TOXICITY AND BIOACCUMULATION STUDIES IN THE SAN DIEGO REGION

WATER BODY AND STUDY	GOALS	RESULTS
DANA POINT AND OCEANSIDE SMALL CRAFT HARBORS:		
State Mussel Watch	Trends	
MISSION BAY:		
State Mussel Watch	Characterization and trends	Results also used for landfill surveillance
Bay Protection, 1993-94, State Water Board	Characterization	
SAN DIEGO BAY:		
State Mussel Watch, 1977-present, State Water Board	Characterization and trends	Tissues show relatively high PCBs and PAHs; results used to locate Bay Protection sampling sites
San Diego Bay Cleanup Project, 1987-90, Regional Water Board	Identification of sources of waste	Sediment chemistry results used to locate Bay Protection sampling sites
Status and Trends, 1987-present, National Mussel Watch and Benthic Surveillance	Characterization and trends	Tissue results confirmed San Diego Bay had elevated levels of PCBs and PAHs
Amphipod toxicity sampling, 1987, USEPA, Rick Swartz	Characterization using Rhepoxynius toxicity	Potential toxic sites identified
Bay Protection, screening, 1992-93, State Water Board	Characterization of toxicity near known sources of waste identified by S.D. Bay Cleanup Project, and identification of reference sites	Potential toxic sites identified

Bay Protection toxicity confirmation, 1993-94; State Water Board; NOAA Status and Trends; and USEPA EMAP	Confirmation of toxic hot spots by resampling at 1992-93 hits, and introduction of randomly-placed sites using stratified sampling

CALIFORNIA BAY PROTECTION AND TOXIC CLEANUP PROGRAM
TECHNICAL QUESTIONS FOR THE
SCIENTIFIC PLANNING AND REVIEW COMMITTEE

General Questions

Questions on general program topics, such as experimental design, sampling strategies, and reference site selection, are covered in additional documentation. The questions below are specific to individual laboratories conducting analyses for the program.

Toxicity Testing

Background

Toxicity testing, using a suite of organisms and protocols, has been used to screen potential hot spots and reference sites. Toxicity tests are also included as part of the "confirmation" phase of the program. If significant toxicity ("associated with toxic pollutants") is observed at least twice in samples from a given site, then that site can be considered a hot spot under the BPTCP hot spot criteria. Toxicity testing methods are described in the BPTCP QAPP.

Questions

1. What criteria should determine toxicity test selection: comparability with other programs, sensitivity, precision, logistics, cost, matrix (solid vs. pore water), others?

2. How important is it to have complete data sets with all sites tested with all species?

3. What criteria should determine when new techniques should be incorporated: State Board Ocean Plan listing, logistical advantages, increased sensitivity or sub-lethal endpoints (especially in solid-phase tests), increased tolerance to non-anthropogenic factors?

4. Should new species or protocols be avoided for the sake of consistency?

5. Should the use of pore water tests be limited because of concerns over ecological relevance or sample handling artifacts, or does their sensitivity and usefulness in TIEs and sediment quality objectives development outweigh those concerns?

6. How does frozen pore water storage affect test results?

7. What are the effects of storage time for fresh pore water?

8. If delays of two days to two weeks are anticipated between sediment collection and pore water testing, should pore water be extracted immediately and then stored, or should solid sediment be stored and pore water extracted immediately before testing?

9. What negative controls are necessary in pore water (lab seawater vs. Reference site pore water)?

10. Should controls be included for all sample manipulations, such as: travel controls, extraction controls, freezing controls (if samples are frozen), brine controls, dilution water controls and/or sample bottle controls?

11. How would multiple controls be used in the statistical analysis of the data?

12. Could all of the above controls be satisfied with pore water from a good reference site?

13. Would multiple reference sites with various grain size, TOC, etc., be necessary for pore water controls?

14. In solid phase tests, are home sediment controls sufficient for comparisons against test sites to determine significant toxicity in this program?

15. If reference sites are necessary for comparisons against test sites to determine significant toxicity, what constitutes an appropriate reference site, and how many are necessary? (This question belongs with the group of issues that must be addressed in the larger context of additional analyses, such as benthic ecology and sediment chemistry.)

16. Should positive control results (reference toxicant test LC50s) be required to fall within a specified range for test acceptability? If control charts are used, must a test LC50 fall within the bounds of 2 standard deviations for the concurrent test of a sediment sample to be acceptable?

17. Can we and/or should we measure pore water DOC to interpret pore water toxicity in relation to measured chemical concentrations?

18. Ammonia and Hydrogen Sulfide

    Background: Ammonia and sulfide are currently measured at the beginning and end of each toxicity test in both overlying water and in interstitial water centrifuged from test sediment. It appears that measuring

overlying water underestimates levels of the two compounds to which the organisms are exposed, and that measuring interstitial water may overestimate exposure, as animals probably avoid high concentrations by inhabiting shallow oxidized layers in the test containers. We are currently sampling for ammonia and sulfide by taking water from as close as possible to the sediment/water interface (<0.5 cm).

Questions on sulfide and ammonia in toxicity tests:

a. How can we best sample test containers to measure concentrations of sulfide and ammonia to which the organisms are exposed

b. Are there reversals or non-monotonic trends in toxicity of ammonia or sulfide?

c. Are some organisms more sensitive to the ammonium ion than to unionized ammonia, and should both be reported?

Benthic Community Analyses

Background

Benthic ecological assessments have been used in the BPTCP "confirmation" phase, after sites have been selected based on past data and toxicity screening. Analyses have focused on indicator species, with diversity, abundance, and biomass also evaluated.

Three to five replicate cores have been collected at each site.

Questions

1. Is there a single index, or should a single index be developed, to describe the condition of a site in terms of its relative ecological degradation?

2. Should choice of indices be based on correlations with chemistry? What other criteria are appropriate?

3. What is the minimum number of field replicates necessary to adequately characterize the condition of the benthic community structure at a site?

4. If cleanup plans are implemented, can benthic community analysis be used in recolonization studies to monitor site recovery after cleanup? If so, what is the best method, and

what studies should be currently undertaken to assist in the study?

5. What seasonal factors need to be considered in planning benthic studies? How are these addressed in long-term program planning?

Trace Organics Chemistry

Background

Trace organic compounds have been measured in bulk sediment (not pore water) at selected sites as part of the "confirmation" phase of the program, after sites have been selected based on past data and toxicity screening. The presence of "toxic pollutants" must be demonstrated in order for a site to be considered a BPTCP hot spot. Compounds on the NOAA analyte list are currently measured. Specific analytical methods are described in the BPTCP QAPP.

Questions

1. Are the analytical techniques adequate to satisfy program goals?

2. Should organic compounds be measured in pore water?

3. Should the number of compounds analyzed for be increased?

4. Should effort be directed toward identification of unknown peaks?

5. Are detection limits adequate for program goals and to allow meaningful correlations with chemistry?

Trace Metals Chemistry

Background

Trace metals have been measured in bulk sediment and occasionally pore water at selected sites as part of the "confirmation" phase of the program, after sites have been selected based on past data and toxicity screening. The association with "toxic pollutants" must be demonstrated in order for a site to be considered a BPTCP hot spot. Aluminum, antimony, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, tin, and zinc are currently measured. Specific analytical methods are described in the BPTCP QAPP.

Questions

1. Are the analytical techniques adequate to satisfy program goals?

2. Should trace metals be measured in pore water routinely?

3. Should the number of metals analyzed for be increased or decreased?

4. Should the laboratory be analyzing AVS routinely?

5. Are detection limits adequate for program goals and to allow meaningful correlations with chemistry?

Biomarkers

Background

A number of biomarkers have been analyzed in special BPTCP studies. Biomarkers may be used to demonstrate environmental "impairment", which, in association with elevated contaminant concentrations in tissues, can lead to hot spot designation. To date, the program has supported work on the following biomarkers:

1. Heat stress proteins in mussels - Brenda Sanders

2. Reporter gene system (luciferase) - UC San Diego and Jack Anderson

3. Cytogenetics - mitotic aberrations in sea urchin embryos - MPSL/UC Santa Cruz

4. Histopathology - gonadal/somatic indices - EROD in fish tissues - UC Davis and Bob Spies

Questions

1. Which biomarkers are most appropriate for the goals of the program?

2. How are candidate biomarkers affected by sampling techniques and other artifacts?

3. What level of within-site precision is necessary for defensible results?

4. How do the effects of temperature, salinity, food availability and seasonal physiological cycles affect the validity of biomarker results?

5. What additional QAQC is necessary for biomarker studies?

6. Are biomarkers necessary? Given the high number of toxicity hits found so far, is the increased sensitivity of biomarkers necessary if their interpretation is difficult to support in a regulatory context?

Natural Toxins and Unknowns

Background

Many sites investigated so far have relatively low concentrations of measured contaminants, yet demonstrate toxicity to test organisms. Ammonia, sulfide, and grain size are measured routinely, but often do not account for toxicity. Natural toxins or unmeasured contaminants may be responsible, and their analysis may facilitate interpretation of the relationships between chemistry and toxicity. Chromatographs often show large peaks for unknown chemicals. There has been no effort to date to evaluate natural toxins or unknown chemicals as part of the BPTCP.

Questions

1. How much effort should the BPTCP invest in natural toxins and unknown chemicals?

2. What is the best and/or most cost effective approach to investigate natural toxins?

3. What are the best analytical techniques?

4. How can we distinguish between natural and anthropogenic biological effects?

Statistics

Background

For the purposes of hot spot designation, the BPTCP must demonstrate significant biological impacts. It may not be sufficient from a regulatory perspective to show simply that a "sample" is significantly toxic relative to a control. More likely it will be necessary to demonstrate that a "site" is significantly more toxic than unimpaired sites or reference conditions. Further, while toxicity data can be analyzed from a single station using laboratory replicates, benthic community data may need to be analyzed on the basis of multiple stations (field replicates) to characterize a site. The BPTCP needs to

establish precise statistical definitions for what is toxic and/or impaired.

Questions

1. How can toxicity and benthic community data be integrated to demonstrate significant differences among sites (with or without field replication)?

2. Is comparison against laboratory negative controls (such as home sediment or laboratory seawater) sufficient to indicate significant toxicity of test sites?

3. Is comparison against a single reference site sufficient to indicate significant toxicity of test sites?

4. What are the best methods for incorporating natural variability among sites (in the absence of pollution) into the determination of significant toxicity?

5. What other sources of variability must be incorporated into statistical methods (field replicate variability, temporal variability, between site variability)?

6. Does a "reference envelope" approach account for all applicable variation, and is such an approach appropriate for this program?

7. Is the Hampel Outlier Identifier method a preferable approach for discriminating between reference sites and toxic sites?

8. What is a reference site? (Note: This issue is and has been taken up in a broader context elsewhere.)

9. We are now conducting site-by-site separate variance t-tests instead of Analysis of Variance and Dunnett's test. Is this the best method? What other possibilities exist (especially when trying to incorporate natural between-site variance)?

10. Along with simple test-specific significance, should we include protocol "detectable difference" criteria based on the cumulative 90% MSD(as suggested by Thursby)?

11. When conducting a large number of individual correlations, must the significance level (alpha) be adjusted to account for the possibility of attaining significant correlation values by random chance? If so, how?

12. Are multivariate techniques (such as principle components analysis) appropriate for the BPTCP efforts to associate chemistry and biological effects?

13. Given program objectives, available funding, and potential for legal scrutiny, what is the most appropriate sampling design for identifying toxic hot spots? For developing sediment quality objectives? For monitoring cleanup efforts? For monitoring bay and estuarine areas that are clean or potentially subject to future pollution?

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A P P E N D I X B

Scientific Planning and Review Committee
Briefing Document for Recommendations
on the Bay Protection and Toxic Cleanup Program
Monitoring Activities

May 1996

Scientific Planning and Review Committee Briefing Document for Recommendations on the Bay Protection and Toxic Cleanup Program Monitoring Activities

May 1996

Department of Fish and Game
Regional Water Quality Control Boards
State Water Resources Control Board

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS
DEPARTMENT OF FISH AND GAME

SCIENTIFIC PLANNING AND REVIEW COMMITTEE:

BRIEFING DOCUMENT FOR RECOMMENDATIONS ON THE BAY PROTECTION AND TOXIC CLEANUP PROGRAM MONITORING ACTIVITIES

MAY 1996

PREFACE

This briefing document was developed to assist the Scientific Planning and Review Committee (SPARC) in preparing for a technical workshop to review the State Water Resources Control Board's Bay Protection and Toxic Cleanup Program (BPTCP) monitoring activities. It contains a summary of the SPARC recommendations on questions posed at the SPARC meeting held on April 12 and 13, 1995 as well as descriptions of the specific issues SPARC will consider and comment on at the Workshop scheduled for May 15-17, 1996.

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TABLE OF CONTENTS

BAY PROTECTION AND TOXIC CLEANUP PROGRAM
SCIENTIFIC PLANNING AND REVIEW COMMITTEE

PURPOSE OF THE TECHNICAL WORKSHOP

The Bay Protection and Toxic Cleanup Program (BPTCP) is a Statewide Program legislatively mandated to identify toxic hot spots in the enclosed bays and estuaries of each of the seven coastal regions of the State. Once toxic hot spots are identified, each coastal Regional Water Quality Control Board is legislatively mandated to develop Toxic Hot Spot Cleanup Plans specifying where and how each identified toxic hot spot will be remediated. The major focus of the Program to date has been monitoring to identify polluted sites.

The BPTCP is sponsoring this workshop to provide a forum for the review of studies performed by the BPTCP. The studies will be reviewed by experts in the fields of toxicology, benthic ecology, organic and inorganic chemistry, program implementation and direction, experimental design, statistics, and bioaccumulation.

The purposes of this workshop are to (1) add and modify, as needed, the SPARC recommendations received at the workshop held on April 12 and 13, 1995 and (2) review the reports developed by the BPTCP, and (3) receive specific advice on appropriate methods for evaluating the monitoring data collected.

Focus of the Workshop

1. Review and incorporation of the SPARC recommendations into the Statewide monitoring approach.

2. Interpretation of toxicity data collected.

3. Interpretation of the benthic community data collected.

4. Setting priorities using a weight-of-evidence approach.

5. Review of the studies of water column toxicity and chemistry in the Central Valley Region.

6. Completion of the discussion on organic chemistry methods.

7. The use of bioaccumulation monitoring techniques.

Contents of the Briefing Document

For each of these topics, a brief issue paper outlining the approaches the BPTCP has taken is presented. In addition to the

issue papers the recommendations from the April 1995 SPARC meeting are listed and the revised monitoring approach is presented.

Each of the topics presented in this document could take several days of discussion to fully evaluate and assess. It is the intent of this workshop that SPARC hear the approaches being pursued by the Program and comment on their appropriateness and usefulness. The SPARC is charged with determining if the approaches the Program is taking are scientifically appropriate and, if not, what approaches the Program should use.

BAY PROTECTION AND TOXIC CLEANUP PROGRAM
SCIENTIFIC PLANNING AND REVIEW COMMITTEE
TECHNICAL WORKSHOP

MAY 15-17, 1996

MOSS LANDING MARINE LABORATORIES SHORE STATION
AND MOSS LANDING CHAMBER OF COMMERCE BUILDING

MOSS LANDING, CALIFORNIA

AGENDA

WEDNESDAY, MAY 15, 1996: Moss Landing Laboratories Shore Station--North

1:00 p.m. to 2:00 p.m.	Register
2:00 p.m. to 5:00 p.m.	Review of SPARC 1995 recommendations and overview of BPTCP progress to date

THURSDAY, MAY 16, 1996: Moss Landing Chamber of Commerce Building

8:00 a.m. to 8:15 a.m.	Welcome
8:15 a.m. to 8:30 a.m.	Introductions
8:30 a.m. to 9:00 a.m.	Overview, previous SPARC recommendations and reports completed
9:00 a.m. to 10:30 a.m.	Interpretation of toxicity data Reference envelope 80% of Controls Others
10:30 a.m. to 10:45 a.m.	Break
10:45 a.m. to 12:00 noon	Interpretation of toxicity data (continued)
12:00 noon to 1:00 p.m.	Lunch
1:00 p.m. to 2:30 p.m.	Interpretation of chemistry data ERM, ERL PEL, TEL Quotients AETs

2:30 p.m. to 2:45 p.m.	Break
2:45 p.m. to 5:30 p.m.	Water column toxicity, Bioaccumulation of pollutants, Organic chemistry methods

FRIDAY, MAY 17, 1996: Moss Landing Chamber of Commerce Building

8:00 a.m. to 8:30 a.m.	Welcome
8:30 a.m. to 10:00 a.m.	Interpretation of benthic community data Benthic index development Assessment of degraded conditions
10:00 a.m. to 10:15 a.m.	Break
10:15 a.m. to 12:00 noon	Weight of Evidence approach Comprehensive interpretation of data Setting priorities for sites
12:00 noon to 1:00 p.m.	Lunch
1:00 p.m. to 3:00 p.m.	Weight-of-evidence approach (continued)
3:00 p.m. to 3:15 p.m.	Break
3:15 p.m. 4:30 p.m.	Wrap-up: SPARC recommendations

MONITORING ACTIVITIES COMPLETED BY THE
BAY PROTECTION AND TOXIC CLEANUP PROGRAM
FY 1995-1996

As part of the legislative mandates of the Program, the BPTCP has implemented regional monitoring programs to identify toxic hot spots (this work is described in SWRCB et al., 1995). Regional monitoring efforts are being implemented in all seven coastal Regions (SWRCB, 1993; SWRCB et al., 1995). Several reports have been completed in the last year.

Each of the reports completed have been submitted to the SPARC for review. A brief description of each of the reports is presented below.

San Diego Bay Report

Three-hundred and fifty stations have been sampled and data analyzed. The first draft of the report was completed by DFG in February, 1996 (Fairey et al., in review).

In this study, San Diego Bay, Mission Bay and the Tijuana River Estuary were sampled. Two sampling designs were used: directed point sampling and stratified random sampling. Measurements of sediment toxicity, benthic community structure and chemicals present in the sediments were made. Three stations were found to satisfy the conditions listed in the definition of a toxic hot spot (DWQ/SWRCB, 1995). Eighty-four other stations were identified to be of moderate and low concern.

Small Bays and Estuaries Pilot Study

The NOAA/EMAP/SWRCB Small Bays and Estuaries pilot study was initiated in March 1995 (SWRCB et al., 1994; SWRCB and NOAA, 1993). This study is a cooperative effort between the SWRCB, NOAA and the EPA Environmental Monitoring and Assessment Program. The draft report on this study is undergoing internal review (Anderson et al., in review).

The pilot study has seven objectives:

1. Estimate with known confidence the percent of degraded fine-grained sediment area in Southern California small bays and estuaries using several critical threshold values of toxicity, benthic community analysis, and chemistry.

2. Produce a map of the data collected for sediment toxicity, benthic community analysis and chemistry.

3. Identify a set of sites that should be revisited for confirmation as either toxic hot spots or reference sites.

4. Assess the effectiveness of locating toxic hot spots and reference sites (for which prior knowledge of likely impacts exists) or random sampling throughout the set of water bodies.

5. Assess the concordance of two solid phase sediment toxicity tests over a range of substrate, salinity, and toxicant concentration conditions.

6. Develop a benthic index for interpretation of benthic data.

7. Identify which of the measured toxicants are most associated with toxic response.

San Francisco Bay Fish Contaminant Study

The draft of this report was released for public review in December 1994. The final report was released at the end of June 1995 (RWQCB et al., 1995). The comprehensive human health risk analysis to be conducted by OEHHA using the study results is currently in-progress, and is expected to require several months. As a result of the data, OEHHA issued an interim health advisory for fish consumption in San Francisco Bay in December 1994.

This study (RWQCB et al., 1995) was conducted to measure contaminant levels in fish caught and consumed by anglers in San Francisco Bay. The main objectives of the study were to identify, to the maximum extent possible, the chemicals, species and geographical areas of concern in San Francisco Bay. This study was designed in a coordinated effort between OEHHA, DFG, the Department of Health Services, environmental groups and anglers. Thirteen fishing piers were sampled for fish with a small habitat range. Other regions of the Bay were sampled for fish that had a larger habitat range. The species of fish that were collected were white croaker (which was the highest priority fish based on its feeding behavior and lipid content), shiner surfperch, walleye surfperch, leopard sharks, brown smoothhound sharks, striped bass, sturgeon and halibut. Pilot Study Screening Values based on the consumption rate of 30 grams per day were used to screen the data for potential chemicals of concern. Results showed that:

1. The EPA guidance document, Guidance For Assessing Chemical Contaminant Data For Use In Fish Advisories- Volume 1- Fish Sampling And Analysis (EPA 823-R-93-002, 1993), was an effective tool for designing the pilot study and analyzing data collected from the San Francisco Bay study.

2. Based on EPA screening values six chemicals or chemical groups were identified as potential chemicals of concern in San Francisco Bay. They were PCBs, mercury, dieldrin, total DDT, total chlordane and the dioxin/furans.

3. High levels of the pesticides dieldrin, total DDT and total chlordane were most often found in fish from the North Bay.

4. Levels of PCBs, mercury and the dioxin/furans were found at concentrations exceeding EPA screening values throughout the Bay.

5. Fish with high lipid content (croaker and shiner surfperch) in their muscle tissue generally exhibited higher organic contaminant levels. Fish with low lipid levels (halibut and shark) generally exhibited lower organic contaminant levels.

6. Of the Bay fish collected, white croaker consistently exhibited the highest tissue lipid concentrations. Lipophilic PCBs and pesticides concentrated to the highest levels in the muscle tissue of these fish.

7. Mercury levels were found to be the highest in the two shark species collected; the leopard shark and the brown smoothhound shark. Both the sharks and white croaker exhibit increasing mercury concentration with increasing fish size indicating bioaccumulation of this metal in Bay area fish.

8. Vallejo-Mare Island was the sampling location from which fish most often exhibited high levels of chemical contaminants. Oakland Inner Harbor also exhibited a high incidence of tissue contamination.

San Francisco Bay Reference Site Study

The main purposes of this study (Hunt et al., in review) are to: (1) identify sediment reference sites in San Francisco Bay to use in toxicity tests, (2) recommend sediment toxicity test protocols to use in monitoring sediment toxicity in San Francisco Bay, (3) develop Sediment Toxicity Identification (TIE) protocols that can be used in San Francisco Bay and (4) identify the cause of toxicity at previously identified reference sites. For this study five potential sediment reference sites were chosen. Two sites were in San Pablo Bay, one site was in the Central Bay and two sites were in the South Bay. Chemical analysis has been conducted at all sites that do not show toxicity. Sediment samples from Tomales Bay and several contaminated sites were also collected. All potential reference sites had three field replicates. In addition, all potential reference sites, except those in the South Bay, were sampled three times during the year during different hydrographic conditions. Since the most likely locations to find reference sites were in San Pablo and the Central Bay, those sites were chosen first. Since these sites seemed to be good reference sites based on results from two sampling events, additional sites were chosen in the South Bay. Between seven to nine toxicity tests were performed on each

sample. These tests were: (1) the 10 day solid phase amphipod test using Eohaustorius, (2) the 10 day solid phase amphipod test using Ampelisca, (3) the 10 day amphipod test using Eohaustorius in undisturbed cores, (4) the 10 day amphipod test using Eohaustorius in pore water, (5) the bivalve larvae development test in pore water, (6) the urchin larvae development test in pore water, (7) the urchin larvae development test using a sediment/water interface exposure, (8) the Neanthes growth and survival test and (9) a 10 day solid phase test using Nubelia. Toxicity tests were dropped out of the study based on the level of control survival, performance at reference sites and sensitivity to contaminated sites.

The first step in this project was to develop Sediment TIE protocols for the 10 day amphipod test, the bivalve larvae development test and the urchin larvae development test. When all laboratory tests were completed including pore water extraction experiments, testing the sensitivity of the various organisms to TIE manipulations and spiking experiments, the field portion of the study began. Samples were collected at the reference sites with enough field replication to try to determine field variability and during different hydrologic conditions to try to determine seasonal variability. By collecting the samples in this way we hoped to identify reference sites, determine the variability at those sites for statistical purposes, and identify sediment toxicity tests that perform well at reference sites but are sensitive to contaminated sites. Once reference sites are identified, testing of these sites will continue and data will be added to develop a "reference envelope" for these sites. In addition, we performed the amphipod test with undisturbed cores and the urchin test using a sediment/water interface to evaluate the environmental relevance of the standard amphipod and urchin tests. These tests could possibly be used in confirming toxic hot spots.

When samples were found to be toxic, a TIE was performed using the pore water test that showed the toxicity. The first two field TIEs were performed on sediment from Islais Creek, where the City of San Francisco has had their main outfall for decades, and on Tomales Bay sediment. After removing ammonia and hydrogen sulfide from the Islais Creek sample, toxicity remained. After running TIEs on both samples results seemed to indicate that in both samples toxicity was being caused by a polar organic degradation product. Additional work has been performed to try to extract and identify the cause of this toxicity. A draft report on this study is currently available.

Stockton Urban Stormwater Runoff (Region 5)

The primary objective of the work is to identify pollutants present in Stockton wet weather urban runoff which cause toxicity in water samples collected from waterways located in the Southern

Delta. Limited testing occurred last year at Stockton which confirmed that runoff from the City was also toxic. Little work has been done on urban runoff linking the responsible pollutant(s) and the observed toxicity. The number of pollutants typically present in urban runoff is extensive and it is not possible to adequately assess toxicity with standard, concurrent chemical analyses. Bioassays and toxicity identification evaluations (TIEs) must be conducted to determine the responsible chemicals. In addition, the toxicity monitoring program at Stockton last year noted suppressed dissolved oxygen levels in water samples collected from Smith Canal, the Calaveras River and Five Mile Slough after the first rainfall event of the year. Board staff and local residents reported observing dead catfish, bass and carp in these waterways. Fish mortality from low oxygen levels would also have occurred in the bioassays had they not been continuously aerated. Continuous aeration is not a normal procedure in these tests. Apparently the dissolved oxygen problem occurs almost annually at Stockton and has repeatedly been reported to the Department of Fish and Game. It is not known whether the oxygen suppression results from biological or chemical oxygen demand nor how extensive (temporally and spatially) the problem is.

This study has two objectives: to identify the specific pollutants present in Stockton urban runoff causing toxicity in bioassays and to identify both spatially and temporally the extent of the oxygen sag. A secondary objective will be to identify whether the oxygen suppression is the result of elevated biological or chemical oxygen demand.

Cache Creek mercury mass loading study (Region 5)

The Central Valley trace metal monitoring program element has three objectives: to define the extent of metal criteria exceedances throughout the Delta, to determine the extent of metal associated toxicity throughout the Delta; and to determine the metal (mostly mercury) loading patterns to the Delta. The latter emphasizes the importance of storm events. Two patterns have emerged after more than two years of study. First, no incidents of toxicity have been linked to metal exceedances. Some exceedances of criteria have occurred but generally appear to be limited to storm events. Second, large amounts of mercury (greater than 95 percent of the annual load) is transported into the Estuary during winter high flow periods. At this time the concentration of mercury exceeds the EPA recommended freshwater criteria of 12 ng/l. Normal dry weather mercury concentrations in the Sacramento River and Delta are between 2 and 4 ng/l. During wet weather water from the Sacramento Valley enters the Delta through both the Sacramento River and the Yolo Bypass (Prospect Slough). Wet weather high flow mercury levels in the Sacramento River ranged between 15 and 40 ng/l and in Prospect Slough between 30 and 600 ng/l. Concentrations as far downstream

as the City of Martinez have been measured at 16 ng/l. The Prospect Slough data suggest a potentially significant source in the Bypass. Follow-up studies of the major inputs to the Bypass found that the Cache Creek watershed was the probable source. Mercury concentrations in the Creek ranged between 600 and 2200 ng/l. High mercury levels were also detected in some other Coast Range creeks discharging to the Sacramento River upstream of the Feather River. All these sources are outside the Delta but are probably responsible for the mercury human health advisory for consumption of fish caught in the Sacramento-San Joaquin Delta Estuary. Follow-up work proposed this coming winter to confirm the mercury sources detected in winter 1995 and to begin evaluating the feasibility of mercury abatement projects. We propose concentrating on Cache Creek for an evaluation of how to proceed with mercury abatement work. If successful, we will use the information gained on Cache Creek to evaluate abatement work on other coastal creeks which contribute elevated mercury loads to the Estuary.

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SCIENTIFIC PLANNING AND REVIEW COMMITTEE RECOMMENDATIONS

An overview of the BPTCP along with its goals and activities was presented at the April 12 and 13, 1995 meeting. The workshop focused on discussion of the following questions identified by the State and Regional Boards and the Department of Fish and Game:

1. What is toxic?

2. How should we show association between toxicity, benthic community, etc. and chemical concentrations?

3. What is a benthic impact?

4. Should we use a probability-based sampling design (random sampling) or directed point sampling approach (i.e. based on best professional judgment)?

5. Should we use a screening and confirmation approach?

6. What biological methods should we use?

7. What chemical methods should we use?

The SPARC provided recommendations to improve the BPTCP monitoring program and specifically addressed the seven questions that needed to be resolved. Further comments and suggestions will be considered and incorporated as they are provided by SPARC.

The SPARC recommendations from the April 1995 meeting follow:

Issue 1. Toxicity

a. The selection of toxic and reference sites will ultimately be a policy decision based on best available scientific approaches for determining biological response.

b. The reference envelope approach is preferred over simple comparison to laboratory controls, and there is agreement that this is the statistical approach to pursue for determining the level of toxicity suitable for meeting toxic hot spot toxicity criterion.

c. All toxicity data should be normalized to laboratory controls to account for any variation in laboratory factors or test organism condition.

d. Compare test site response to large reference envelope population from a comprehensive data base of reference site results for the protocol used.

e. Compare test site response to reference envelope population from samples collected concurrently with test samples.

f. A site is toxic if it falls below the reference envelope lower bounds for both the reference site data base and concurrent samples.

g. If a site is toxic relative to the large reference envelope population from the comprehensive database, but concurrent reference site results are also low, the site should be revisited.

Selection of Reference Sites Within Each Region

Some level of pollution will always be unavoidable. However, reference sites should be selected through the following process:

a. Reference sites should not include those sites where toxicity is observed in association with pollution. Common sense and knowledge of local conditions should be used in order to avoid areas known to be disturbed or polluted.

b. Randomly sample the rest of the water body, conducting analyses of chemistry, benthic community structure, and toxicity.

c. Allow trained benthic ecologists to select the sites that have moderate to high species richness, abundant presence of amphipods or other indicator species, and any other indicator of ecological health that can be argued convincingly.

d. Evaluate the chemistry data and narrow the sites to those that do not exceed more than one upper value (such as PEL or ERM) for existing chemistry guidelines.

e. Evaluate the toxicity data and eliminate only those sites that have extremely high toxicity, as determined by a qualified toxicologist, not by a priori criteria.

f. Once reference sites are chosen they are sampled along with test sites. Include the new reference site toxicity results

in the reference envelope regardless of the magnitude of the toxicity response. The reference envelope toxicity result will fall where it may.

g. Compile a data base of toxicity responses from appropriately selected reference sites, and include past and current reference site data in the reference envelope. Allow the number of data points in the reference envelope to grow as more studies are completed in the area.

Issue 2. Association of Chemistry and Biological Effects

a. Causal relationships are more powerful than correlations in providing evidence of links between pollutant concentrations and biological effects.

b. Development of spiked bioassay data is recommended to allow unit approach to identifying chemicals responsible for observed effects.

c. Simultaneous Extracted Metals and Acid Volatile Sulphides (SEM/AVS) data is essential for understanding metal effects.

d. Measurement of Dissolved Organic Carbon (DOC) is recommended to help understand organic and metal bioavailability.

e. The effect of oxidation state of chemical compounds should be investigated.

f. Pore water toxicity and chemistry are valuable in determining causal relationships.

g. It is recognized that sorbed pollutants may become bioavailable after ingestion and metabolism.

h. Professional judgement and knowledge of local conditions should be used to decide how best to allocate resources to determine causal relationships.

i. The Program should use all available criteria and biological measurements in assessing the relationships between chemistry and biological effects (i.e., use weight of evidence approach).

Issue 3. Benthic Impacts

No single index is defensible in a regulatory setting. A site should be characterized as "healthy", "intermediate", or "degraded" based on the best professional judgement of a

qualified ecologist, using whatever methods are most appropriate to the site.

Replication of Benthic Ecological Analysis

An analysis of existing data should be conducted to determine benthic replication, keeping in mind the types of analyses that can be done with benthic data, the cost of the analysis and benefits derived. Do not replicate unless there is a clear reason to do so.

Issue 4. What is the most appropriate sampling design

a. During the screening phase, sampling should incorporate a stratified random design in order to provide an opportunity to find unknown toxic hot spots.

b. Confirmation phase sampling should be based on grids covering the site of concern, with random placements of stations within grid blocks.

c. Grids should be configured to match site characteristics.

d. Temporal variations should be accounted for with repeated sampling at locations at least one meter apart.

e. Spatial and temporal scales should be based on knowledge of the site.

Field Replication

a. Random sampling over suitable sized grids may be preferable to replication. There is no need to replicate unless there is a clear and defensible reason why.

b. It would be best to conduct statistical analysis of past data to determine replication needs for future work.

Issue 5. Toxic Hot spot designation (Screening and Confirmation approach)

a. A three tiered data analysis approach should be used. This would include chemical, toxicity, and benthic community analyses. Having hits in all three components of a triad analysis, would classify a site as a worst case toxic hot spot. Hits on fewer than all three would result in classification as a site to be concerned about. All sites could be ranked in this way.

b. Under the BPTCP, the screening phase would consist of using either toxicity or benthic community analysis or chemistry or bioaccumulation data or some combination of all of these. Screening should be flexible, designed to fit the Regional Board's needs. Analysis in this phase should be done only when needed to provide sufficient information to convince the Regional Boards to list or consider the site as a priority site of concern for further action. A hit in either of these analyses would elicit concern, trigger confirmation phase monitoring under the BPTCP and/or perhaps prompt a specific Regional Board to pursue some other type of regulatory review action. It would be very important to involve potential responsible parties as early in the process as possible and coordinate studies and funding.

c. The confirmation phase should consist of toxicity and chemistry and benthic community analyses on a previously visited site of concern or wherever previous evidence indicates a site may be impacted. A confirmatory hit in toxicity, benthic community structure; or all three analyses performed during this phase would classify a site as a worst case toxic hot spot, assuming that there was a hit registered during screening. This phase could also include intensive investigations to identify causal relationships, and intensive grid sampling necessary to show gradients and spatial extent.

d. Allow for a mechanism for de-listing sites if intensive studies prove preliminary designation was in error.

e. It is important to focus on the most impacted sites for successful toxic hot spot designation and application of regulatory actions.

Issue 6. Appropriate Biological Methods

a. Use the amphipod 10 day solid phase test and the sea urchin 96 hour larval development test in pore water for screening sites.

b. Use the amphipod solid phase test, the sea urchin larval development test in pore water, and the sea urchin larval development test at the sediment water interface (SWI) for confirmation. (A sensitive chronic test, such as the 28 day protocol for Leptocheirus, or tests using resident species may also be useful for confirmation).

c. Centrifuge pore water for bioassay testing. Frozen storage is probably acceptable if necessary.

d. Pore water dilutions are not necessary for screening, but do provide additional information for confirmation.

e. Pore water toxicity coupled with chemical analyses may be useful for establishing relationships between chemistry and biological effects.

f. Use of the Neanthes test should be discontinued because it provides no additional information beyond that provided by the amphipod and sea urchin protocol.

g. Studies should be conducted to investigate whether inhibition of embryo/larval development in pore water or solid phase (SWI) exposures can be correlated, or,is associated with ecological perturbation, such as impacts on benthic community structure.

Biomarkers

a. Biomarker analyses are currently difficult to interpret in terms of ecological effects. These types of analyses should not be used for toxic hot spot designation at present.

b. Biomarker analyses may be useful in monitoring cleanup activities to determine if there is continued exposure to pollutants.

Bioaccumulation

Recruit the services of a bioaccumulation expert into SPARC and examine how bioaccumulation can be used in the BPTCP.

Issue 7. Appropriate Chemical Methods

Metals

a. Perform SEM/AVS.

b. Use performance-based approach rather than rigid USEPA protocols.

c. Do bulk-phase metals in screening.

d. Do pore water metals to help determine causality for confirmation and cleanup planning

e. Preserve original samples for pore water chemistry.

f. Sediment samples can be frozen for a year for chemical analysis.

Organics

The April 1995 meeting ended before the organic chemical methods could be fully discussed. Nevertheless, similar recommendations to metal chemical methods were made. Further examination of this topic is scheduled for the next SPARC meeting.

a. The analyte list should be expanded to include Diazinon and other organophosphate pesticides

b. Use performance-based approach rather than rigid USEPA protocols.

c. Do bulk-phase organics in screening.

d. Do pore water organics to help determine causality for confirmation and cleanup planning

e. Preserve original samples for pore water chemistry.

f. Sediment samples can be frozen for a year for chemical analysis.

Overall summary of SPARC recommendations

a. Base program decisions on defensible science to provide common ground for all participants and interested parties.

b. Prepare workplans in advance to allow adequate scientific review, efficient allocation of funds, and timely reporting.

c. Use a carefully considered weight-of-evidence approach to accomplish program goals.

d. Include a bioaccumulation expert on the SPARC panel and examine how bioaccumulation can be used in the BPTCP. Thought should be given to reconciling the two different aspects of toxic hot spot designation: human health risk vs. observed ecological effects.

e. Food web models are not sophisticated enough to allow development of sediment quality criteria based on fish tissue concentrations. The mobility of most fish species limits utility for designation of toxic hot spots on a reasonable scale.

f. Site specific investigations are necessary for toxic hot spot designations. Focus immediately on sites most likely to be successfully designated as a toxic hot spot, and demonstrate program capacity for restoring environmental value to polluted sites.

g. Regional Boards must have more authority and take more responsibility for the planning of work in their respective regions. Local knowledge should be used to focus on the most relevant sites and analyses.

h. In designating toxic hot spots, follow a three-tiered approach: (1) carry out a flexible screening phase using any analysis of the triad or bioaccumulation technique (or); (2) a confirmation phase using all triad analyses (and); (3)intensive site specific studies demonstrating spatial extent, and causal relationships between pollutants and observed biological effects. It is very important to bring the potential responsible parties into the process as early as possible.

i. Confirmation and intensive cleanup studies should use a stratified random sampling design, with grids of suitable size to cover the area of concern. Field replication of all measures (toxicity, chemistry, benthic community structure, and bioaccumulation) should only be used when there is a clear and valid reason.

j. Statistical significance of toxicity should be determined based on a comparison to a reference envelope.

k. Benthic community degradation should not be based on a single index. A single community index is too easily discredited. Benthic community degradation should be based on convincing evidence determined on a site specific basis by a qualified ecologist.

l. Performance-based chemistry should be used.

m. Pore water toxicity, concurrent chemistry and spiked assays may be useful to determine associations between pollutants and biological effects. Correlations are not nearly as convincing in demonstrating associations. A TIE approach would also provide evidence of cause-effects relationships but should be used judiciously because of cost.

n. SEM/AVS are recommended for all samples.

o. Statewide and site-specific chemical objectives should be pursued.

p. Bioavailability concerns complicate interpretation of solid-phase sediment toxicity testing in evaluating the relationships between pollutant and biological effects.

q. Solid-phase sediment toxicity testing is useful for sediment quality assessment and toxic hot spot designation.

Region-specific SPARC Recommendations

Region 1

If local problems can be identified without toxicity screening then proceed to use the available resources as effectively as possible.

Bioaccumulation data may be appropriate to identify problem chemicals, biological exposure and potential sources of pollution in Region 1.

Biological effects measurements (toxicity screening or benthic community analysis) should be considered in cases where unknown toxic hot spots are present.

Region 2

Sampling should be done in a way to avoid mixing oxic and anoxic sediment regardless of sampling depth. Do the experiment necessary to show the effects of changes in oxidation state on toxicity and toxicity/chemistry relationships.

Use appropriate amphipod species based on knowledge of species tolerance limits to ammonia, salinity, and grain size.

Determine how to include bioaccumulation data into toxic hot spot screening.

Region 5

Pursue monitoring of pesticide degradation products.

Request that the SWRCB, Regional Boards, and Federal agency executive management agree to coordinate monitoring programs and share information from studies in the Bay-Delta. Also that the two Regional Boards pursuing BPTCP work in the Bay-Delta coordinate in the planning and monitoring work.

REVISED STATEWIDE MONITORING DESIGN

This section comprises the revised Statewide monitoring approach for the BPTCP. The section was taken from the SPARC briefing document (SWRCB, et al. 1995) and revised to incorporate the SPARC recommendations. Revisions are included in the text in ~~strikeout~~ (deletions) and ***bold italics*** (additions).

Legislative Mandate

Section 13391.5 of the Water Code defines toxic hot spots as "...locations in enclosed bays, estuaries, or adjacent waters in the 'contiguous zone' or the 'ocean' as defined in Section 502 of the Clean Water Act (33. U.S.C. Section 1362), the pollution or contamination of which affects the interests of the State, and where hazardous substances have accumulated in the water or sediment to levels which (1) may pose a substantial present or potential hazard to aquatic life, wildlife, fisheries, or human health, or (2) may adversely affect the beneficial uses of the bay, estuary, or ocean waters as defined in the water quality control plans, or (3) exceeds adopted water quality or sediment quality objectives."

Specific Definition of a Toxic Hot Spot

One of the most critical steps in the development of toxic hot spot cleanup plans is the identification of hot spots. Once they are identified the parties responsible for the sites could be liable for the cleanup of the site or further prevention of the discharges or activities that caused the hot spot. Because the cost of cleanup or added prevention could be very high, the SWRCB is considering categorizing toxic hot spots to distinguish between sites with little information (potential toxic hot spots) and areas with significantly more information (candidate toxic hot spots).

Proposed Specific Definition

Although the Water Code provides some direction in defining a toxic hot spot, the definition presented in Section 13391.5 is broad and somewhat ambiguous regarding the specific attributes of a toxic hot spot. The following specific definition provides the RWQCBs with a specific working definition and a mechanism for identifying and distinguishing between "potential," "candidate" and "known" toxic hot spots. A Candidate Toxic Hot Spot is considered to have enough information to designate a site as a Known Toxic Hot Spot except that the candidate hot spot has not been approved by the appropriate Regional Water Quality Control Board. Once a candidate toxic hot spot has been adopted into a

toxic hot spot cleanup plan then the site shall be considered a known toxic hot spot and all the requirements of the Water Code shall apply to that site.

a. Potential Toxic Hot Spot

The Water Code requires the identification of suspected or "potential" toxic hot spots (Water Code Section 13392.5). Sites with existing information indicating possible impairment, but without sufficient information to be classified further as a "candidate" or "known" toxic hot spot are classified as "potential" toxic hot spots. Four conditions sufficient to identify a "potential" toxic hot spot are defined below. If any one of the following conditions is satisfied, a site can be designated a "potential" toxic hot spot:

1. Concentrations of toxic pollutants are elevated above background levels, but insufficient data are available on the impacts associated with such pollutant levels to determine the existence of a known toxic hot spot;

2. Water or sediments which exhibit toxicity in screening tests or tests other than those specified by the State or Regional Boards;

3. Toxic pollutant levels in the tissue of resident or test species are elevated, but do not meet criteria for determination of the site as a known toxic hot spot, tissue toxic pollutant levels exceed maximum tissue residue levels (MTRLs) derived from water quality objectives contained in appropriate water quality control plans, or a health advisory for migratory fish that applies to the whole water body has been issued for the site by OEHHA, DHS, or a local public health agency, the waterbody will be considered a potential toxic hot spot. Further monitoring is warranted to determine if health warnings are necessary at specific locations in the waterbody.

4. The level of pollutant at a site exceeds Clean Water Act Section 304(a) criterion, or sediment quality guidelines or EPA sediment toxicity criteria for toxic pollutants.

b. Candidate Toxic Hot Spot:

A site meeting any one or more of the following conditions is considered to be a "candidate" toxic hot spot.

1. The site exceeds water or sediment quality objectives for toxic pollutants that are contained in appropriate water quality control plans or exceeds water quality criteria promulgated by the U.S. Environmental Protection Agency.

   This finding requires chemical measurement of water or sediment, or measurement of toxicity using tests and objectives stipulated in water quality control plans. Determination of a toxic hot spot using this finding should rely on recurrent measures over time (at least two separate sampling dates). Suitable time intervals between measurements must be determined.

2. The water or sediment exhibits toxicity associated with toxic pollutants ***that is significantly different from the toxicity observed at reference sites (i.e., when compared to the lower confidence interval of the reference envelope),*** based on toxicity tests acceptable to the State Water Resources Control Board or the Regional Water Quality Control Boards.

   To determine whether toxicity exists, recurrent measurements (at least two separate sampling dates) should demonstrate an effect. Appropriate reference and control measures must be included in the toxicity testing. The methods acceptable to and used by the BPTCP may include some toxicity test protocols not referenced in water quality control plans (e.g., the Bay Protection and Toxic Cleanup Program Quality Assurance Project Plan). Toxic pollutants should be present in the media at concentrations sufficient to cause or contribute to toxic responses in order to satisfy this condition.

3. The tissue toxic pollutant levels of organisms collected from the site exceed levels established by the United States Food and Drug Administration (FDA) for the protection of human health, or the National Academy of Sciences (NAS) for the protection of human health or wildlife. When a health advisory against the consumption of edible resident non-migratory organisms has been issued by OEHHA or DHS, on a site or waterbody, the site or waterbody is automatically classified a "candidate" toxic hot spot if the chemical contaminant is associated with sediment or water at the site or water body.

Acceptable tissue concentrations are measured either as muscle tissue (preferred) or whole body residues. Residues in liver tissue alone are not considered a suitable measure for known toxic hot spot designation. Animals can either be deployed (if a resident species) or collected from resident populations. Recurrent measurements in tissue are required. Residue levels established for one species for the protection of human health can be applied to any other consumable species.

Shellfish: Except for existing information, each sampling episode should include a minimum of three replicates. The value of interest is the average value of the three replicates. Each replicate should be comprised of at least 15 individuals. For existing State Mussel Watch information related to organic pollutants, a single composite sample (20-100 individuals), may be used instead of the replicate measures. When recurrent measurements exceed one of the levels referred to above, the site is considered a known toxic hot spot.

Fin-fish: A minimum of three replicates is necessary. The number of individuals needed will depend on the size and availability of the animals collected; although a minimum of five animals per replicate is recommended. The value of interest is the average of the three replicates. Animals of similar age and reproductive stage should be used.

4. Impairment measured in the environment is associated with toxic pollutants found in resident individuals.

Impairment means reduction in growth, reduction in reproductive capacity, abnormal development, histopathological abnormalities.~~, or identification of adverse effects using biomarkers.~~ Each of these measures must be made in comparison to a reference condition where the endpoint is measured in the same species and tissue is collected from an unpolluted reference site. Each of the tests shall be acceptable to the SWRCB or the RWQCBs.

Growth Measures: Reductions in growth can be addressed using suitable bioassay acceptable to the State or Regional Boards or through measurements of field populations.

Reproductive Measures: Reproductive measures must clearly indicate reductions in viability of eggs or offspring, or reductions in fecundity. Suitable measures include: pollutant concentrations in tissue, sediment, or water which have been demonstrated in laboratory tests to cause reproductive impairment, or significant differences in viability or development of eggs between reference and test sites.

Abnormal Development: Abnormal development can be determined using measures of physical or behavioral disorders or aberrations. Evidence that the disorder can be caused by toxic pollutants, in whole or in part, must be available.

Histopathology: Abnormalities representing distinct adverse effects, such as carcinomas or tissue necrosis, must be evident. Evidence that toxic pollutants are capable of causing or contributing to the disease condition must also be available.

~~Biomarkers: Direct measures of physiological disruption or biochemical measures representing adverse effects, such as significant DNA strand breakage or perturbation of hormonal balance, must be evident. Biochemical measures of exposure to pollutants, such as induction of stress enzymes, are not by themselves suitable for determination of "candidate" toxic hot spots. Evidence that a toxic pollutant causes or contributes to the adverse effect are needed.~~

5. Significant degradation in biological populations and/or communities associated with the presence of elevated levels of toxic pollutants.

   This condition requires that the diminished numbers of species of individuals of a single species (when compared to a reference site) are associated with concentrations of toxic pollutants. The analysis should rely on measurements from multiple stations. Care should be taken to ensure that at least one site is not degraded so that a suitable comparison can be made.

   In summary, sites are designated as "candidate" hot spots after generating information which satisfies any one of the five conditions constituting the definition.

c. Known Toxic Hot Spot:

A site meeting any one or more of the conditions necessary for the designation of a "candidate" toxic hot spot and has gone through a full State or Regional board hearing process, is considered to be a "known" toxic hot spot. A site will be considered a "candidate" toxic hot spot until approved as a known toxic hot spot in a Regional Toxic Hot Spot Cleanup Plan by the Regional Water Quality Control Board and approved by the State Water Resources Control Board.

Monitoring Program Objectives

The four objectives of BPTCP regional monitoring are:

1. Identify locations in enclosed bays, estuaries, or the ocean that are potential or candidate toxic hot spots. ***Potential toxic hot spots are defined as suspect sites with existing information indicating possible impairment (criteria above) but without sufficient information to be classified further as a candidate toxic hot spot.***

2. Determine the extent of biological impacts in portions of enclosed bays and estuaries not previously sampled (areas of unknown condition);

3. Confirm the extent of biological impacts in enclosed bays and estuaries that have been previously sampled; and

4. Assess the relationship between toxic pollutants and biological effects.

Review of Preliminary Studies and Research

Each of the seven RWQCBs participating in the program has assembled information that was used to develop a preliminary list of potential and candidate toxic hot spots (SWRCB, 1993). ***Further monitoring will be initiated by each RWQCBs participating in the program by preparing a toxic hot spot monitoring identification workplan identifying sites suspected to be impaired by pollutants or sites already identified as areas of concern. The workplan will specify if the sampling is for screening or confirmation and should include a list of types of analyses to be performed at each site. The workplan information will be assembled with input from Department of Fish and Game, SWRCB, and OEHHA staff based on the knowledge of local conditions and best professional judgement plus any pertinent scientific information obtained through either previous BPTCP screening or confirmation results or through information provided by other monitoring programs.***

Biological Monitoring Methods

The tests listed in Table 1 are acceptable to measure water and sediment toxicity. Other tests may be added to the list as deemed appropriate by the State or Regional Water Boards provided the tests have a detailed written description of the test method; inter-laboratory comparisons of the method; adequate testing with water, wastewater, or sediments; and measurement of an effect that is clearly adverse and interpretable in terms of beneficial use impact.

Chemical Methods

The BPTCP measures a variety of organic and inorganic pollutants in estuarine sediments (Stephenson et al. 1994). The BPTCP requires its laboratories to demonstrate comparability continuously through strict adherence to common Quality Assurance/Quality Control (QAQC) procedures, routine analysis of certified reference materials, and regular participation in an on-going series of inter-laboratory comparison exercises (round-robins). This is a "performance-based" approach of quality assurance.

The method used by the BPTCP are those used in the NOAA National Status and Trends Program (Lauenstein et al. 1993) and the methods documented in the DFG QAQC Manual (DFG, 1992). Under the BPTCP performance-based chemistry QA program, laboratories are not required to use a single, standard analytical method for each type of analysis, but rather are free to choose the best or most feasible method within the constraints of cost and equipment.

Sampling Strategy

Screening Sites and Confirming Toxic Hot Spots

~~In order to identify known toxic hot spots a two tier process was used. The first tier was a screening step where at least two toxicity tests were used at a site (Tables 2 and 3).~~ ***In order to identify toxic hot spots a two step process is used. Both steps are designed around a three tiered analysis approach (Triad analysis) plus an optional bioaccumulation information component. The Triad analysis consists of toxicity tests as listed in Table 2 (results from tests in Table 1 are also acceptable), benthic community analysis as characterized by the best professional judgement of the scientists performing the analysis, and performance-based chemical analysis for metals and organic chemicals. Screening and confirmatory phase toxicity tests specifically used by the BPTCP are listed in Table 2. Data***

collected in the screening and confirmation phases are listed on Table 3.

The first step is a screening phase that consists of measurements using toxicity tests or benthic community analysis or chemical tests or bioaccumulation data to provide sufficient information to list a site as a potential toxic hot spot or a site of concern. Sediment grain size, total organic carbon (TOC) and H_2S concentration are measured to differentiate pollutant effects found in screening tests from natural factors. ~~Chemical analyses (metals and organics) were performed on a subset of the screening samples.~~

A positive result or an effect in any of the triad tests would trigger the confirmation step (depending on available funding). ~~If effects were found at sites by these screening steps, some sites were retested (depending on available funding) to confirm the effects.~~ *The confirmation phase consists of performing all components of the triad analysis: toxicity, benthic community analysis, and chemical analysis, on the previously sampled site of concern or wherever previous evidence indicates a site may be impacted. A candidate THS is a station that has significant effect measured in the toxicity tests or benthic community analysis coupled with chemistry information that shows that pollutants could contribute to the observed effects. A hit in toxicity and chemistry, benthic community analysis and chemistry or all three components of the triad analysis would classify a site as a candidate toxic hot spot (as described in the candidate THS criteria listed above).* ~~In the confirmation step measurements were replicated and compared to reference sites or conditions. Chemical measurements (metals, organics, TOC, H_2S) and other factors (e.g., sediment grain size) were measured. Measurements of benthic community structure and, if needed, bioaccumulation were also made.~~

Table 1
Water and Sediment Toxicity Tests That Meet
the Criteria For Acceptability

Type of Toxicity Test	Organism Used		Reference
	Common Name	Scientific Name	
Solid Phase Sediment	Amphipod	Rhepoxynius	ASTM, 1993
	Amphipod	Eohaustorius	ASTM, 1993
	Amphipod	Ampelisca	ASTM, 1993
	Amphipod	Hyalella	ASTM, 1993
	Sea Urchin	***Strongylocentrotus***	***Anderson et al., 1995***
	~~Polychaete~~	~~Neanthes~~	~~Johns et. al., 1990~~
Sediment Pore Water~~*~~	Bivalve larvae	Crassostrea	ASTM, 1993
		Mytilus	ASTM, 1993
	Abalone larvae	Haliotis	Anderson et al., 1990
	Echinoderm fertilization	Strongy-locentrotus	Dinnel et al., 1987; with modification by EPA, 1992
	Giant kelp	Macrocystis	Anderson et al., 1990
	Red alga	Champia	Weber et al., 1988
	Fish embryos	Atherinops	Anderson et al., 1990
		Menidia	Middaugh et al., 1988
		Pimephales	Spehar et al., 1982
	Cladoceran	Daphnia	Nebecker et al., 1984
		Cereodaphnia	Horning and Weber, 1985
Ambient Water	Bivalve larvae	Crassostrea	ASTM, 1993
		Mytilus	ASTM, 1993
	Abalone larvae	Haliotis	Anderson et al., 1990
	Echinoderm fertilization	Strongylocen-trotus	Dinnel et al., 1987; with modifications by EPA, 1992
	Giant kelp	Macrocystis	Anderson et al., 1991
	Red alga	Champia	Weber et al., 1988
	Mysid	Holmesimysis	Hunt et al., 1992
	Fish embryos	Atherinops	Anderson et al., 1990
		Menidia	Middaugh et al., 1988
		Pimephales	Spehar et al., 1982
	Fish larvae	Atherinops	Anderson et al., 1990
		Menidia	Peltier and Weber, 1985 Weber et al., 1988
		Pimephales	Peltier and Weber, 1985 Weber et al., 1988
	Cladocerans	Daphnia	Nebecker et al., 1984
		Cereodaphnia	Horning and Weber, 1985

~~*Pore water tests (other than amphipods) alone can not be used to designate a candidate toxic hot spot.~~

Table 2

Screening and Confirmation Tests for
Toxic Hot Spot Identification

Test Organism	Type	End Point
Rhepoxynius, Eohaustorius (Amphipod)	Solid Phase	Survival*(10 day)*
~~Haliotus, Mytilus, Crassostrea~~	~~Overlying water~~	~~Shell development~~
Strongylocentrotus (Sea urchin)	Sediment pore water Sediment/water Interface (Confirmation only)	***72-96 hour*** ~~Fertilization~~ development~~, and/or anaphase aberration~~
~~Neanthes (Polychaete worm)~~	~~Bedded sediment~~	~~Survival and growth~~

A Battery of Screening Tests

Selecting a battery of toxicity screening tests (Table 2) can improve cost-effectiveness by expanding the range of potential impacts to be evaluated. Although recurrent toxicity must be demonstrated to qualify a site as a "candidate" toxic hot spot, the degree of certainty for each of the measurements does not necessarily have to be equivalent. The cost of confirming toxicity at a site can be prohibitively high, especially if it includes a large number of field replicates and extensive reference site testing. The screening tests should allow for a relatively rapid lower cost assessment of the site. ***Toxicity screening test should include an amphipod solid phase test and a sea urchin larval development test in pore water. Confirmation toxicity test should include an amphipod solid phase test, a sea urchin larval development test using pore water, and a sea urchin larval development at the sediment/water interface (Tables 2 and 3).***

~~Even though the list of acceptable tests is long (see Table 1), the State and Regional Water Boards have used between two and four tests to screen sites (Table 2). For all screening, at least one amphipod test was performed. Other tests were performed as needed depending on funding availability, the needs of collaborators (such as the National Oceanic and Atmospheric Administration or the EPA Environmental Monitoring and Assessment Program), test organisms sensitivity to the~~

Table 3

Types of Data *To Be* Collected in Regional Monitoring Programs for the Identification of Toxic Hot Spots

Type of Data	Screening	Confirmation
Toxicity testing	Suite of ~~4~~ ***2*** tests (see Table 5)	~~Repeat of positive results~~ ***Suite of 3 tests***
Field replicates	None	if needed
Lab replicates	Five	Five
Reference sites	Reference Envelope	Reference Envelope
Physical analysis	Grain size	Grain size
Chemical analyses	Ammonia, hydrogen sulfide, TOC, pesticides, PCB, PAH, TBT, metals, ***AVS/SEM***	Ammonia, hydrogen sulfide, TOC, pesticides, PCB, PAH, TBT, metals, ***AVS/SEM***
Benthic community analysis	Optional	~~Required~~ ***Optional***
Bioaccumulation	Occasionally	Occasionally (sites with no pre-existing bioaccumulation data)

Table 4

Sequence of Tasks for Designating Toxic Hot Spots

1.	Select toxicity screening sites.
2.	Sample screening sites.
3.	Conduct battery of two toxicity screening tests; or Benthic community analysis; or Chemical analysis; or bioaccumulation. ~~analyze~~ ***measure*** for hydrogen sulfide, ammonia, TOC, and grain size.
4.	Determine whether quality assurance requirements have been met.
5.	Report on Items 3 and 4.
6.	Select ~~and match~~ hits and ~~potential~~ reference ***envelope*** sites. ~~for ammonia, hydrogen sulfide, and grain size.~~
~~7.~~	~~Conduct metals and organic chemical analysis on subset of screening sites from Item 6.~~
7~~8~~.	Determine whether quality assurance requirements have been met.
8~~9~~.	Report on Item~~s~~ 7 ~~and 8~~.
9~~10~~.	Select sites ~~and toxicity tests~~ for confirmation and reference ***envelope*** sites.
10~~11~~.	Sample confirmation and reference ***envelope*** sites.
11~~12~~.	Conduct ~~subset of the~~ battery of ~~toxicity~~ tests which were screening hits; analyze for hydrogen sulfide, TOC, ***DOC,*** and conduct benthic community analysis.
12~~13~~.	Conduct ***bulk phase, pore water or both,*** metals and organic chemical analyses, ***plus SEM/AVS***.
13~~14~~.	Determine whether quality assurance requirements have been met.
14~~15~~.	Report on Items ~~12~~ *11* through ~~15~~ *14*.
15~~16~~.	Conduct statistical and other analyses to determine whether sites qualify as candidate toxic hot spots.

~~pollutants expected to be present, and the media (bedded sediment or pore water) thought to be contaminated.~~

Site Selection

Two somewhat different approaches ~~were~~ ***are*** used in BPTCP monitoring. Six of the coastal RWQCBs have used a design that combines toxicity testing, chemical analysis, and benthic community analysis in a two-phased screening-confirmation framework (Tables 3 and 4).

The Central Valley RWQCB, with jurisdiction over the Sacramento-San Joaquin Delta, has designed its program to respond to Delta conditions and to the water quality problems characteristic of that area. Fresh water toxicity testing combined with water chemistry (metals and pesticides) constitutes the main program components. Sediment toxicity testing could be added to the monitoring design at a later stage.

Four different categories of sites have been identified for sampling in the BPTCP monitoring program: (1) potential toxic hot spots base on existing information, (2) high risk sites *of* ***concern*** based on existing information ***and local knowledge of the area,*** (3) stratified random sites, and (4) reference sites ***to be included in the reference envelope***.

Potential toxic hot spots are the highest priority sites because some ~~indications~~ ***information*** already exists that these sites have a pollution-related problem. The~~se~~ data ***associated with these*** sites indicate ~~are typically sites with information available on~~ chemical contamination of mussel tissue, data documenting water and sediment toxicity, measurements of metals or organic chemicals in sediments, ~~and~~ or ~~occasionally~~, biological impairment. These sampling efforts are typically point estimates.

There are many other sites that are considered "high risk" ***sites of concern*** even though we have no monitoring information to support this contention. High risk sites are locations where a nearby activity (such as marinas, storm drains, and industrial facilities) are thought to be associated with a certain risk of toxicity. The measurements at high risk sites ***of concern*** are either point estimates or selected probabilistically ***or suspected problem sites on the basis of local knowledge***.

When little is known about the quality of a waterbody segment, the monitoring efforts should use a stratified, random sampling approach. ***This would be used during the screening phase in order***

to provide the opportunity of finding new toxic hot spots and ~~*as well as These random sites are useful*~~ ***help*** in determining the quality of larger areas in the State's enclosed bays and estuaries. This probabilistic approach will allow for the State and Regional Water Boards to make better estimates of area (percentage) of water bodies that is impacted. The State and Regional Water Boards have used the techniques used by the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (SWRCB et al. 1994).

Reference sites

~~Locating reference sites requires identification and testing of a variety of potential reference sites encompassing the expected range of grain size, TOC, and other characteristics. Existing data sets that describe chemical contamination, grain size, and TOC at marine and estuarine sites are reviewed. Since these sources yield an insufficient number of sites, fine grained areas presumed to be relatively free of contamination are also examined. These sites may likewise prove to be rare, so sites with chemicals present, but experiencing low energy tidal flushing, will also be sampled. Sites with previous indication of no pollution, and those lacking sediment toxicity measurements will also be sampled. Finally, random selection of sites (as described above) may prove useful in locating reference sites.~~

Locating reference sites requires identification and testing of a variety of potential sites encompassing the expected range of grain size, TOC, and other characteristics. ***In selecting a reference site common sense and knowledge of local conditions should always be used to avoid areas known to be disturbed or polluted. Some criteria to consider in defining a reference condition are as follow:***

1. ***High amphipod abundance***
2. ***High species richness***
3. ***Sediment tolerance for non-treatment effects (NH_3, H_2S, grain size temperature, salinity, etc., (Table 5) above or below which biological effects could be attributed relatively to pollutant toxicity.***
4. ***Sites with low Chemistry (below median values ERM, PEL, etc.)***

After excluding known unacceptable areas the remaining water bodies are randomly sampled (screening phase tests or existing information can be used). The samples are analyzed for chemistry, toxicity, and benthic ecology. The chemistry data is evaluated in order to select the sites that do not exceed more than one upper value for existing chemistry criteria. The

Table 5. Non-Treatment Limits for 10-d sediment toxicity tests with Ampelisca abdita, Eohaustorius estuarius, Leptocheirus plumulosus, or Rhepoxynius abronius (U.S. EPA. 1994).

Parameter	*Ampelisca abdita*	*Eohaustorius estuarius*	*Leptocheirus plumulosus*	*Rhepoxynius abronius*
Temperature(^{0}C)	20	15	25	15
Overlying Salinity (%)	>10	0-34	1.5-32	<25
Grain Size (% silt/clay)	>10	full range	full range	<90
Ammonia (total mg/l,pH 7.7	<30	<60	<60	<30
Ammonia (UI[1] mg/L,pH 7.7	<0.4	<0.8	<0.8	<0.4
Sulfides	NA	NA	NA	NA

[1] UI = unionized ammonia

toxicity data is evaluated to eliminate those sites that have extremely high toxicity. Finally, the reference envelope sites are chosen on the basis of moderate to high species richness, abundance of amphipods or other indicator species, and any other indicator of ecological health that can be argued convincingly.

Once reference sites are chosen for a particular area they are re-sampled along with the test sites during the confirmation phase.

Determination of toxic hot spots will be achieved by comparing the test site toxicity response against a sufficiently large reference envelope of a population of reference site responses. The reference envelope will include results from all reference sites in a particular area, past and present. The reference envelope approach, currently under development, will be used to determine whether the level of toxicity exceeds the lower confidence interval of the reference envelope. As more reference site toxicity results become available more will be known on the range of organism responses found within a reference site condition. This will provide a better tool for determining differences between the toxicity response at reference sites relative to the level of toxicity responses at impacted sites.

<u>Toxicity Screening</u>

All tests include controls which ~~were~~ ***are*** conducted in media known to exert minimal stress on test organisms. Both positive (toxicant present) and/or negative (toxicant absent) controls ~~were~~ ***are*** used to ensure that test organisms are responding within expected limits (Table 3).

The screening step begins with the collection of a single field sample from each site (Table 4, Steps 1 and 2). Five laboratory replicates are required to accommodate statistical comparison with the control. Ammonia and hydrogen sulfide analyses are performed on the media of all tests (Table 4, Step 3) to determine their relative contribution to any observed toxic effects. Grain size and TOC values are determined on all sediment samples to evaluate the response of the organisms to these factors. ~~Although the lack of field replicates restricts statistical comparisons with other sites, this approach allows the BPTCP to test more locations for toxicity within the allocated funding.~~ ***Screening can include the use of chemistry, toxicity tests, benthic community structure analysis, or bioaccumulation monitoring. The analysis is designed to be flexible, and to fit the Regional Board's needs to provide sufficient information to warrant listing a site as a potential toxic hot spot or pursue some other type of regulatory action.***

All these data, along with an assessment of quality assurance performance, are reviewed. Toxicity hits and potential reference ***envelope*** sites are selected and matched for ammonia, hydrogen sulfide, grain size, and TOC. Sites with hits in either one of the tests performed are candidates for re-sampling during the confirmation phase.

Confirmation (i.e., Qualification as Candidate Toxic Hot Spots)

Some of the screening sites (Table 4, Steps *9* ~~10~~ and *10* ~~11~~) with at least one positive test result will be revisited to evaluate the recurrent nature of the toxicity, impacts on the benthic community or high concentrations of specific pollutants. This requires repeat testing of potential toxic hot spots by ***performing the three components of the triad analysis: toxicity, benthic community analysis, and chemistry. This phase could also include intensive investigations to identify causal relationships and grid sampling to show gradients and spatial extent.*** ~~to ensure that toxicity was present or absent. Confirmation testing was more intensive because of (1) addition of field replicates (three to a site); (2) comparison to reference sites (unless water toxicity is the focus); and (3) benthic community analysis (Table 3).~~

~~For each positive toxicity test at a screening site, confirmation was performed for the same test.~~ ~~Generally,~~ Benthic analysis ~~was also performed and~~ ***will*** *be* added to an ever-enlarging nearshore benthic community database which will be periodically evaluated to determine whether impacted and non-impacted sites can be distinguished (Table 4, Step ***11*** ~~12~~). ~~When either recurrent toxicity was is demonstrated with a positive confirmation test or benthic impacts are were suspected, chemical analysis were also performed (Table 4, Step 13).~~ Careful review of all quality assurance procedures ~~was~~ is conducted and, upon approval, will be followed by statistical analysis of the data. ~~Compared to screening, this analysis will be is more comprehensive. and will include measures of field variability in toxicity, benthic data, and reference site conditions.~~

Once both toxicity and benthic impacts have been confirmed through comparison with an appropriate reference ~~site~~ ***envelope*** ~~and appear to be due to human causes~~ the site will be declared a candidate toxic hot spot. When toxicity is present but benthic impacts are lacking, careful analysis will be performed to determine whether the two results are in conflict. Similarly, when toxicity is not demonstrated but benthic impacts are observed, careful review will be conducted to determine whether the same explanation prevails or whether some factor other than

toxicants may be responsible. In either case, decisions about a particular site will be based upon best scientific judgement after careful consideration of the evidence gathered. Further characterization of the site (such as areal extent, range of effects, and source determination) will be described in the cleanup plan ~~and is not intended (unless samples are collected using a random or stratified random design) under this phase of the program.~~

Quality Assurance

The BPTCP Quality Assurance Project Plan (Stephenson et al. 1994) presents a systematic approach that has been implemented within each major data acquisition and data management component of the program. Basic requirements specified in the QAPP are designed to: (1) ensure that collection and measurement procedures are standardized among all participants; (2) monitor the performance of the various measurement systems being used in the program to maintain statistical control and to provide rapid feedback so that corrective measures can be taken before data quality is compromised; (3) assess the performance of these measurement systems and their components periodically; and, (4) verify that reported data are sufficiently complete, comparable, representative, unbiased, and precise.

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TOXICITY ISSUE PAPER

Statistical Methods for Distinguishing Sites of Concern Using the Reference Envelope Approach: Issues to be Resolved

At the April 12-13, 1995 meeting of the BPTCP SPARC, the committee expressed general support for the Reference Envelope statistical approach presented by Bob Smith. This approach is based on the use of toxicity test data from reference sites to describe a population of values indicative of general ambient conditions in a given water body or group of water bodies. From this population of values, a tolerance limit can be calculated that serves as a cutoff for determining significant toxicity relative to the general condition of the water body. This approach is described below, followed by a list of issues that need to be resolved in order to apply this approach in study plans under consideration by the program.

Rationale for the Reference Envelope Approach

For the purposes of identifying sites of concern in the BPTC Program, it is necessary to distinguish between sites where toxicity is clearly indicative of localized pollution and sites where test results are more characteristic of background response. Since samples from a group of study sites would be expected to produce some level of variation in toxicity test response even in the absence of pollution, a method is required to determine what level of test response is significantly greater than expected of samples representing general water body conditions. In many heavily urbanized estuaries, it is probable that all sites have some degree of contamination and some resulting potential for causing adverse biological effects. However, logistical constraints require that efforts be focused on sites where it can be convincingly demonstrated that observed toxicity is due to localized pollution rather than to background variability. In this context, the terms "background", "ambient" or "reference" are defined as representative of general water body conditions, rather than conditions thought to exist prior to anthropogenic influence.

Reference Envelope Statistical Method

The concept of the reference envelope is described here, as taken from Bob Smith's notes from the previous SPARC meeting. A manuscript containing more details is available from Bob Smith upon request.

Sampling Design

An effectively random sample of a population of locations (stations) representative of the "natural background" of indicator values for the area of interest is required. This "natural background" may contain some toxicity or contamination, e.g., Tomales Bay or San Pablo Bay. The chosen hot spots should be "hotter" than the background condition, since it is not practical to remediate very large areas, nor is it legally defensible to penalize someone for local toxicity no worse than that found in the larger area in general.

The random sample of stations will be used to characterize what will be called a reference population. In a statistical test, potential hot spots will be compared to this reference population.

Statistical Test

We would like to see if potential hot spots are unusual (in the direction of toxicity or "badness") compared to the reference population. We can use a statistical test to estimate if a potential hot spot is outside a chosen percentile of the reference population distribution (in the direction of toxicity). The percentile chosen for the test would reflect how "unusual" relative to the reference population a station must be in order to be declared a hot spot. For example, if considering % survival for a bioassay test, one might pick the 1st percentile. This would mean that a station would have to be associated with % survival lower than 99% of the reference population in order to be called a hot spot.

The statistical test is used to identify an indicator value (e.g., a % survival value) that can be used as a cutoff or threshold to distinguish between the reference population and a hot spot (as far as the indicator is concerned). A one-tailed tolerance interval bound will accomplish this. The tolerance interval is based on the variance of the random sample of reference stations, and will therefore incorporate the important sources of natural variation among station locations. The tolerance interval also accommodates the uncertainty involved in estimating the mean and variance of the reference population and the test stations.

The computed tolerance interval bound is equivalent to the edge of a "reference envelope", thus this is called the reference envelope approach. This implies that the reference population is largely contained within a figurative reference envelope, and outliers (potential hot spots) are found outside the envelope.

We can compute the toxicity level that will cover the p^{th} percentile 1 minus alpha proportion of the time as the lower bound (L) of a tolerance interval (Vardeman 1992) as follows:

$$L = X_r - [\, g_{a,p,n} * S_r \,]$$

where X_r is the mean of the sample of reference stations, S_r is the standard deviation of the toxicity results among the reference stations, and n is the number of reference stations. The g values can be obtained from tables in Hahn and Meeker (1991) or Gilbert (1987). S contains the within- and between-location variability expected among reference locations. If the reference stations are sampled at different times, then S will also incorporate between-time variability. We call L the "edge of the reference envelope" because it represents a cutoff toxicity level we will use to distinguish toxic from non-toxic sediments. The value used for p will depend on the level of certainty needed for a particular regulatory situation.

The population of reference values and estimates of the p^{th} percentile of the reference distribution are shown in Figure 1.

Issues Regarding Use of the Reference Envelope Approach

Reference Site Selection Criteria

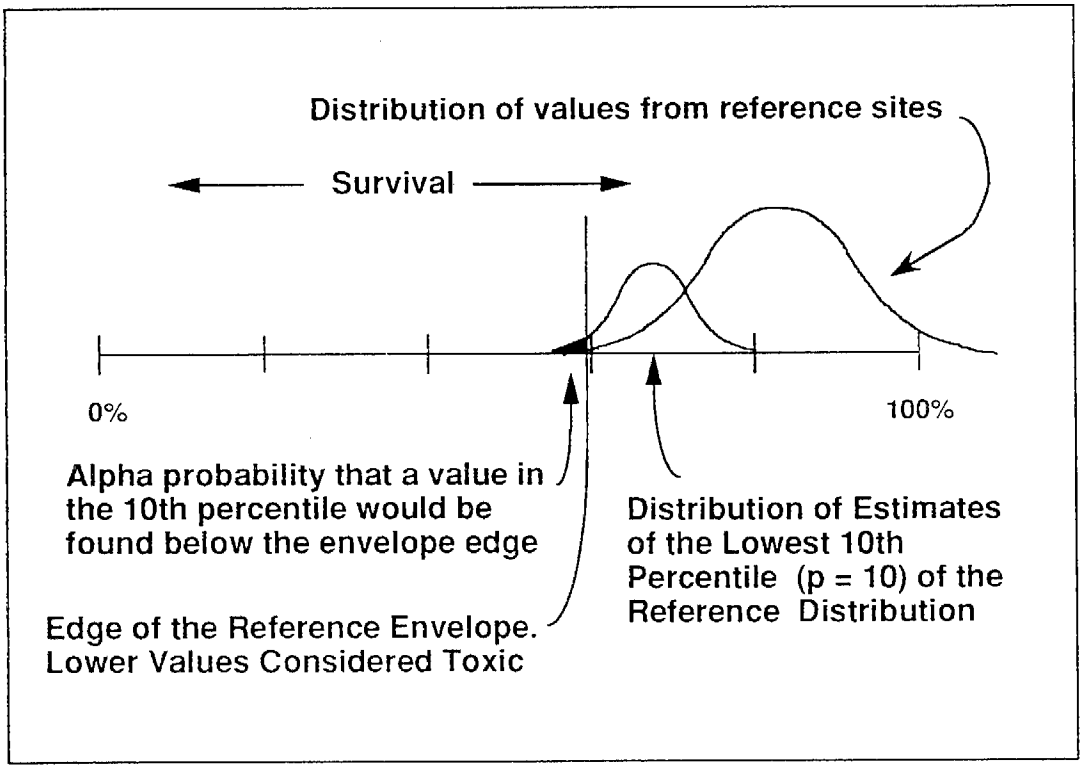
At the April 12-13, 1995 meeting of the BPTCP SPARC, the committee decided that reference sites should be chosen based on data from chemistry and benthic community analyses that indicate low levels of pollution and lack of impacts to benthic communities. It is assumed that both reference and test sites must have physical parameters of grain size and salinity within the tolerances of the test organisms.

Chemistry Criteria

In the BPTCP San Diego Bay study and Southern California Coastal Lagoons study, sites were eliminated from consideration as reference sites if any chemicals for which ERM and/or PEL values have been derived exceeded either of those values. In the Southern California Coastal Lagoons Study, DDT and DDT metabolite concentrations above the ERM were allowed if they were below the SEC concentration derived by MacDonald (1994).

In the San Francisco Bay Reference Site Study, all reference sites exceeded the PEL value for chromium and the ERM and PEL values for nickel. Nickel is ubiquitous in San Francisco Bay, and has been shown to be toxic only at pore water concentrations much higher than corresponding ERM values (Anderson et al.,

Figure 1. Schematic illustration of the method for determining the lower tolerance interval bound (edge of the reference envelope) to determine sample toxicity relative to a percentile of the reference site distribution.



1995). AVS/SEM data were not available to evaluate potential impacts of these metals. Total DDT was found to be above ERM and PEL values at one field replicate of one candidate reference site. The concentration of dibenz(ah)anthracene barely exceeded the PEL in one sample at another candidate reference site but this concentration was half of the ERM.

Benthic Ecology Criteria

In studies of San Diego Bay and the Southern California Coastal Lagoons, sites were classified as "degraded", "undegraded", or "transitional" based on the total number of species per station, the total number of individuals per station, the number of crustacean species per station, and the presence of indicator species (either positive or negative). Sites classified as "undegraded" were eligible for use as reference sites.

Benthic ecology data were not used in the selection of reference sites in San Francisco Bay because of the magnitude of seasonal fluctuations in species composition and the impact of invading exotic species.

Questions Regarding Reference Site Selection Criteria

1. Are the chemistry selection criteria appropriate?

2. How should elevated concentrations of DDT and nickel be evaluated?

3. Should AVS/SEM ratios be used in place of ERM or PEL values in determining metals concentrations allowable at reference sites?

4. How should test organisms tolerances to ammonia and hydrogen sulfide be factored into reference site selection?

5. Are the benthic selection criteria appropriate?

6. Should site toxicity data be considered at all? If so, how?

7. How should site location with respect to pollution sources and other "common sense" considerations be factored into the selection process?

How Many Reference Sites are Necessary?

The reference envelope approach provides a tolerance limit that serves as the threshold for toxicity test results. Percent survival below the tolerance limit indicates significant sample toxicity. The calculation of this tolerance limit is influenced by the reference population mean and variance, and by the number of reference sites. The more reference sites available, the

tighter the distribution, and the higher the tolerance limit (assuming high survival in reference site samples).

The effect of reference sample size on calculation of the tolerance limit is indicated by the table of g values. As presented above, the tolerance limit is calculated by subtracting the product of the reference population variance and the appropriate g statistic from the reference population mean. Therefore, the lower the g value, the closer the tolerance limit will be to the population mean. For an alpha value of 0.05 and a p value of 10% (lowest 10th percentile), g varies with n as follows:

n:	2	3	4	5	6	7	8	9	10	15	20	30	50	120
g:	20.6	8.2	4.2	3.4	3.0	2.8	2.6	2.5	2.4	2.1	1.9	1.8	1.6	1.5

Question: How many reference sites are necessary to adequately compute the tolerance limit?

How Often Must Reference Sites Be Sampled?

The main question here is, if we were to decide that 10 reference sites are necessary, must all ten reference sites be sampled and tested every time a test sample is analyzed, or can historic data be included in the population of reference values used to make the comparison?

If previous data can be used, how should this be done?

1. Create a data set of reference site toxicity values appropriate for each type of test condition (salinity, grain size, physical features). This would generate a single tolerance limit that could always be used as a toxicity threshold.

2. Create a reference data set as above, but add new concurrent reference site data each sampling run.

3. Compare test site data against both concurrent and historic reference site data. Would a site be toxic if it were outside <u>either</u> the concurrent or historical set of reference values, or would it need to be outside <u>both</u>?

4. What details need to be worked out from a statistical perspective to allow comparisons against historical reference data?

How Many Reference Populations Are Necessary for Analysis of California Sites?

How closely do reference sites need to match test sites in terms of:

1. Grain size

2. TOC

3. Salinity

4. Physical Environment (e.g., coastal lagoon, human-made harbor, estuary, open bay, etc.)

5. Human Environment (e.g., dredging history, history of pollutant inputs).

Are multiple reference populations necessary within a single water body, such as San Francisco or San Diego Bay?

Interactions Between Policy and Science

How should policy and scientific perspectives be reconciled in the following areas:

1. Selection of reference sites?

2. Choice of p values in calculating reference envelope tolerance limits?

3. Identification of toxic sites?

What Should Be Done When the Analysis Doesn't Work?

In some cases, variability among reference site responses to some protocols can lead to very low tolerance limits. In the San Diego study, tolerance limits for some pore water tests were below zero. In such cases, significant toxicity would be impossible to detect, regardless of test sample response. Can test data be used in hot spot designation under such circumstances?

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CHEMICAL ASSOCIATION ISSUE PAPER

Use of Sediment Quality Guidelines

ERM and PEL Quotients

In the San Diego and S.Cal. EMAP reports, comparisons of the data to effects-based numerical guidelines (TELs & PELs; ERLs & ERMs) were made to relate sediment pollution to a national scale. Additionally, these guidelines were used to identify individual chemicals of concern for sediment quality management within both regions. Also, a new technique was used for rankings and comparisons using ERM-quotients (ERMQ) and PEL-quotients (PELQ). These were summations of chemical concentrations, divided by their respective ERM or PEL value, for the 30 chemicals for which guidelines have been developed. Cases where levels of measured chemicals were below the analytical method detection limit (MDL), a value of one-half the MDL was used for summations. This is a simple approach for addressing overall chemical pollution where there are multiple pollutants at a station, and is in addition to the standard chemical by chemical approach. Synergistic effects are possible, but not implied by the quotient summations, therefore, this method should be recognized only as a ranking scheme meant to better focus management efforts on interpretation of ambient sediment chemistry data.

Interpretations using ERM and PEL quotients were limited to statistical analysis within this dataset because the approach has not been formally presented in other report. A number of San Diego Bay Region stations were characterized by low levels of pollution so the data set was not normally distributed. A root x+0.5 transformation was applied to achieve a normal distribution. Using the CHI-square test with 90% confidence interval for the 229 stations on which chemical analysis was performed, stations with an ERMQ > 14.6 or a PELQ > 16.3 were found to fall above this confidence interval. Points falling above the 90% confidence interval have a very low probability of being from the same theoretical random distribution as those falling within the interval. Although these values of 14.5 and 16.3 cannot be considered threshold levels with proven ecological significance, they are useful for regional comparative purposes. In the San Diego data set, forty-one stations exhibited ERM or PEL summary quotient levels exceeding the confidence interval cutoffs. Of these forty-one stations, twelve received benthic community analysis, all which were found to have degraded benthic communities. All forty-one stations were tested for *Rhepoxynius* toxicity, of which 29% demonstrated significant toxicity, at the 48% limit established by the reference envelope method. This difference in biological response to pollutants, between benthic community structure and bioassays, is a topic SPARC may wish to

discuss. These differences may be explained by long term exposure to pollutants in the benthic community relative to short term (10 day) pollutant exposure in bioassay tests. Use of the ERM and PEL quotients appear to give a worthwhile representation of overall chemical pollution and were used in both reports for station rankings and characterizations.

Chemical Association Issues

1. Is the use of summary quotients an acceptable data analysis technique?

2. Is the 90% confidence interval an appropriate cutoff value?

3. What variables make summary quotients better predict benthic community degradation than amphipod toxicity.

FRESHWATER STUDIES ISSUE PAPER (REGION 5)

Water Column Toxicity Issues

As part of the Bay Protection Toxic Cleanup Program, Regional Board staff have established a monitoring program in the Delta to determine if Delta waters exceed either the narrative toxicity objective or water quality criteria for metals The focus has been on water column testing instead of sediment testing because previous work has demonstrated that acute toxicity is common in surface water samples collected from the Central Valley Region. Before sediment testing can be addressed we need a solid understanding of water column toxicity issues. In addition to emphasizing water column over sediment issues, we have focused on linking toxicity detections with Toxicity Identification Evaluations (TIEs). Once the chemical responsible for toxicity has been identified we then focus on the chemical, its source, its impact on the Delta and a cleanup strategy.

Delta Toxicity and Metals Monitoring

Bioassay monitoring has been conducted using the EPA freshwater three species protocols. In the first 18 months of the program (1993-94), the bioassay program was composed of two parts: a multi seasonal, fixed station monitoring effort, and a series of special studies designed to follow-up on high priority incidences of toxicity. During this first year, 24 sampling sites were located in the Delta representing all major riverine inputs (the Sacramento, San Joaquin, and Mokelumne Rivers), sites along the major channels carrying this water across the Delta to the pumps or to San Francisco Bay, a number of back slough sites draining urban and agricultural areas along the Delta's periphery and a number of agricultural drains from representative Delta Islands. In addition to toxicity testing, seven of these sites were monitored for metals. Finally, when toxicity was detected, archived samples were submitted for pesticide analyses (because in previous testing toxicity had always been linked to pesticides). On samples which exhibited acute toxicity to *Ceriodaphnia*, TIEs were performed to identify the specific pesticide responsible for the mortality.

The testing has identified bioassay mortality in the Sacramento River (fathead minnow), in the south Delta sloughs surrounding the City of Stockton during rainfall events (*Ceriodaphnia*), in the Sacramento and San Joaquin Rivers after application of orchard dormant spray insecticides (January and February; *Ceriodaphnia*) and in Delta back sloughs during the early irrigation season (spring and early summer; *Ceriodaphnia*) . In addition, algal toxicity has been detected in the south Delta during the period when fish barriers restrict flow in this

region, in the sloughs surrounding Stockton following rainfall events and in Delta back sloughs. However, in all cases additional information is needed either to better define the hot spot incidents, aid in development of cleanup plans or help prioritize future work. Not all incidents of toxicity have been linked to a chemical, but in the instances where TIE has been conducted, only pesticides have been identified as toxicants. No metal toxicity has been detected. Staff is currently attempting to link specific pesticides to specific agricultural processes.

Metals monitoring at the fixed sites suggests that exceedances of EPA metals criteria are uncommon. Peak metal values occur during storm events when increased flows cause an increase in total suspended sediment. The most significant finding is the high load of mercury entering the Delta from both the Sacramento River and the Yolo Bypass. Detailed studies in 1994-95 and 1995-96 have determined that Cache Creek is a major source of mercury to the Bypass. Preliminary work in the watershed suggests that the loads originate after heavy rains in an unaccessible 20 mile reach of Cache Creek canyon downstream of Clearlake and Indian Valley Reservoir and upstream of Bear Creek. Follow-up studies next rain season should identify the source. In addition Region 5 has funded UC Davis to collect aquatic organisms from the Cache Creek watershed with an emphasis on the area that appears to export large amounts of mercury to ascertain local aquatic bioavailability.

Issues and Questions

1. At the upcoming Scientific Planning and Review Committee Meeting, Central Valley Regional Board staff will present an over view of our three year program outlining the approach taken to identify water column "hot spots". Does this approach make sense?

2. Should water column "hot spots" be defined or treated differently than sediment "hot spots"?

3. We have used the toxicity testing approach as a screen for surface water problems. Several pesticides have been identified. These pesticides are additive in their toxicity (all are acetylcholinesterase inhibitors) and are frequently found concurrently or sequentially. Cumulatively, are they impacting the health of the Delta? What studies could be done to answer this question?

4. Are there areas where the SPARC Committee thinks we need more information? That is, should our remaining resources be focused on more toxicity testing, chemistry work or defining the duration, magnitude and frequency of these pesticide pulses?

5. Long lived fish in the Estuary have elevated mercury body burdens. This has resulted in a fish mercury health advisory. It is clear that large amounts of mercury are still entering the Estuary and it seems possible with more work to identify sources and develop detailed mercury load estimates both in Cache Creek and elsewhere upstream on the Sacramento River. Local bioavailability can also be assessed. However it is unclear how to ascertain the bioavailability of the various sources of mercury once in the Estuary. This is important as the State has limited funds and mercury abatement work should focus on those sites which result in the greatest amount of both local and estuarine bioavailable mercury. Does the SPARC have suggestions on how to proceed with ascertaining the degree to which the various mercury sources are bioavailable once in the Estuary?

BIOACCUMULATION ISSUE PAPER

The Use of Bioaccumulation Monitoring in the Bay Protection and Toxic Cleanup Program

Background

The Bay Protection Toxic Cleanup Program (BPTCP) legislation mandates in part that the State Water Board develop and adopt Sediment Quality Objectives (SQO) and base these objectives "on human health risk assessment if there is a potential for exposure of humans to pollutants through the food chain to edible fish, shellfish, or wildlife". Human exposures do occur for those chemicals that bioaccumulate and SQO were to be developed for highly bioaccumulative chemicals. Although the development of numeric SQO is on hold, public health is still being protected in the BPTCP by occasional monitoring of sport fish for bioaccumulative chemical residues, by narrative SQO and by identifying and designating toxic hot spots based on their established potential for human health risk. This potential is recognized based on the existence of a fish consumption advisory on a waterbody. Such advisories are based on the analysis of metals and organic compounds in muscle tissue of sport fish from the waterbody. Thus, fish bioaccumulation data are currently used in the BPTCP to support narrative SQO and the identification of hot spots, and could be used for future development of numeric SQO.

Existing California Bioaccumulation Data

Some potentially relevant bioaccumulation data exists from the California State Mussel Watch (MWP) and Toxic Substances Monitoring Programs (TSMP). Department of Fish and Game (DFG) carries out the sampling and analysis of both programs and reports the result to the State and Regional Water Board(s). Both programs are focused on monitoring known or suspected water impacts not on the overall assessment of statewide water quality. In addition, Region 2 (San Francisco Bay) has developed a regional monitoring program to identify long term trends in water quality in their region. This program also gathers bioaccumulation data from transplanted mussels.

Mussel Watch has been in existence since 1977 and uses transplants of marine mussel species (Mytilus sp.) and also freshwater clams (Corbicula flumiea)to monitor trace elements and organic compounds in state water bodies. Bags of mussels are hung in the water column for 2 to 6 month exposures. Soft body parts are collected and frozen for analysis without depuration. Composites, not individuals, are analyzed. Soft body parts excluding gonads are used for trace metal analysis. And soft body parts including gonads are used for analysis of organic

compounds. Much of the monitoring has occurred in bays and estuaries. Sampling sites are usually determined by Regional Water Board staff with knowledge of local water bodies. Sites are not necessarily sampled on a seasonal, yearly, or repeat schedule in most regions. The regional monitoring program in Region 2 does include sampling twice a year at established stations.

TSMP was initiated in 1976 to monitor trace elements and organic compounds (e.g., pesticides and PCBs) in endemic fish and other aquatic life (e.g., crayfish) in fresh, estuarine and marine waters in California. A variety of fish species have been sampled during the history of the program. Fish of various sizes may be sampled and effort is made to collect the same species at multiple stations. Samples may be composites of whole fish, fish livers, or fillets. Much of the monitoring has occurred in inland lakes, rivers and estuaries. Again Regional Water Board staff are instrumental in determining monitoring sites, but no consistent schedule of repeat sampling has been used throughout the state.

Three regional fish sampling efforts separate from MWP and TSMP have been undertaken in Santa Monica Bay, San Diego Bay and Monterey Bay for the purpose of evaluating the human health risks of eating fish from these areas. Sampling was done by DFG and fillet samples of sport fish species of legal size were analyzed for metals and organics in these studies. As a result of these studies a number of fish consumption advisories have been issued and many are still in force. Occasional studies of sport fish have also been done in freshwater lakes in the state, and consumption advisories are still in force for several sites.

There is no state-wide program to regularly monitor sport fish for chemical residues in tissue. When monitoring data are available the Office of Environmental Health Hazard Assessment (OEHHA) evaluates the health risk of eating fish from the sampled location and issues consumption advisories if the potential risk is excessive. Fish tissue data may be from studies commissioned by industry, city, county, state or federal agencies and programs.

Bay Protection Toxic Cleanup Program Data

A pilot study of sport fish contamination in San Francisco Bay was undertaken by the San Francisco Regional Water Quality Control Board in 1994. This study sampled a number of representative sport fish species caught and consumed in the San Francisco Bay area. This study analyzed metals and organic compounds in composite fillet samples taken primarily from legal sized fish sampled near fishing piers or other locations where people fish. As a result of a preliminary analysis of this data an interim fish consumption advisory was issued for the whole of

San Francisco Bay by OEHHA. A comprehensive risk assessment of this data is being conducted by OEHHA.

While analysis of the data show that several chemicals have accumulated to levels of potential health concern in some bay caught fish it has been difficult to determine if certain sites are potentially more contaminated based on the tissue residue data alone. Limited sample size and the effects of confounding biological factors (e.g., lipid level and fish size) have complicated this effort.

Sample Design Questions

1. Should probability based sampling be used for fish tissue sampling? What about for transplants of mussels, etc.?

   Site-directed sampling has typically been used for both. Fish are sampled at fishing sites and mussels tend to be placed near suspected pollutant sources.

2. Are separate screening and confirmation sampling recommended for bioaccumulation?

   For human health concerns once you get multiple composites from a single waterbody with elevated tissue concentrations of pollutant an advisory may be issued. This would often occur before or without 'confirmation' sampling.

   'Confirmation' (second samples at a later date) fish samples are often of species not sampled and analyzed in the first sampling event. Different species sampled in the second event are targeted to see if they are as contaminated as those species in the first sampling.

3. Should temporally separated samples be used? required? When they exist how should they be interpreted? Are they meaningful for identifying hot spots over a 1 year time-frame, a 5 year time-frame, 10 years?

   Mussel Watch sample data may be available from 5 or more years ago. This may be useful to choose target locations for sampling but should these data be used to designate hot spots? How should they be interpreted?

   Fish advisories may still be in effect based on sample data from 5 or more years ago. There is no regular repeat sampling of water bodies for which an advisory has been issued, although this type of program is currently being planned for San Francisco Bay. The advisories are in force until data is gathered that shows tissue levels have been

reduced to a level that is no longer a potential health risk.

Fish samples from one sampling event may actually reflect exposure averaged over multiple years.

4. Are physically separated samples recommended? When they exist how should they be interpreted, i.e., at what distance do they represent a single sediment exposure source or multiple exposure sources?

   Transplanted mussels reflect a more discrete exposure.

   Resident fish may reflect exposures from more than one discrete location and prior years.

5. Should whole fish samples be taken in addition to fillet samples?

   Muscle tissue samples are necessary for human health risk assessment interpretations. Skin and fat may be removed. These samples are not very useful for wildlife risk assessment.

6. Are 'replicate' samples of a single species necessary?

   Sampling protocols to collect data for health advisories typically try for multiple composites (2 minimum) of the most abundant fish species or one that is frequently consumed.

   Different sized composites are used for different fish species, e.g., for San Francisco Bay study:

shiner surf perch:		20
croaker:		5
large surf perch (e.g. white)		5
shark	3	
halibut	3	
sturgeon		3
striped bass:		3

   Always target legal sized fish caught and eaten by sport fishers. Seldom sample fish caught exclusively by wildlife.

7. Should transplanted mussels be depurated before the chemical concentration is determined? Some of chemical level determined prior to depuration may be in gut, not absorbed and accumulated in tissue. A special BPTCP study in San Francisco Bay to evaluate the MWP protocol showed no significant difference between non-depurated and depurated mussels.

Are water filtering mussels (depurated or non-depurated) a useful measure of bioavailability and/or indicative of a potential or candidate hot spot in sediment? Would mollusks that filter sediment be better?

8. Should resident species other than fish (e.g., resident crabs, clams, mussels, etc.) be used for monitoring bioaccumulation? Some of these species are collected recreationally. Are these potentially more useful than transplanted mussels for identifying hot spots? Region 1 (North Coast) has used resident species for monitoring in Humboldt Bay.

9. How should bioaccumulation sampling be incorporated in the overall screening sampling design? In most cases at present sediment samples are collected, toxicity tests are run, and sediment is archived for later chemistry. Bioaccumulation samples (especially fish), like other chemistry analyses, are expensive to run and have additional costs and difficulties associated with sampling. However, there is concern that we may be missing locations where significant bioaccumulation is occurring without toxicity.

10. Are fish studies, which by there nature reflect a larger area, more useful to identify hot spots than mussel studies, which reflect a smaller area?

    Would it be useful to attempt a general screen of fish contamination for major bays and estuaries? This might be used to establish 'background levels' and sampling could be independent of toxicity sampling. Or should the focus be on linking fish sample locations to toxicity sample sites?

11. Can bioaccumulation measures stand alone to determine hot spots or do they need to be linked to other biological indicators (e.g., toxicity, benthic community analysis, or biomarkers)?

Analysis Questions

1. Is the reference site concept applicable to fish?

   It is not used in human health risk assessment, although some consideration may be included of 'background' tissue concentrations. Should we be trying to sample background chemical levels for sport fish? Could this information be used to determine hot spots (e.g., defined as locations above background) or clean spots that are of no further concern?

2. Can Mussel Watch data be used as substitute or adjunct to AVS and SEM to show evidence that metals are bioavailable?

Relationship between Bioaccumulation/Human Health & Aquatic Toxicity

1. Do the hot spots based on aquatic life (primarily determined by toxicity) and human health criteria (primarily determined by exposure potential) lead to different sorts of hot spots?

   Those defined by aquatic life have the potential to be in a smaller discrete area and short lived.

   Those defined by human health are potentially hard to focus on a discrete area and may reflect longer lived conditions and possibly deeper sediment.

2. Do we need to reconcile these differences? Are the differences useful?

3. Can we associate the two results? How? Via sediment chemistry, biomarkers, stomach content chemistry, chemistry on younger (non-legal size) fish, or etc.? Is this association necessary or merely satisfying?

Interpretation/designation of Hot Spot Questions

1. Should mussel transplants in the water column be used for designating sediment hot spots? Can they be incorporated as part of the weight-of-evidence for designating a hot spot?

   Existing Mussel Watch data are often used by Regional Boards to help pick sample sites.

2. Should resident mussels or other invertebrate species be given equal or greater weight compared to transplanted mussels for designating sediment hot spots? Should sediment filtering/ingesting/dwelling species be given greater weight?

3. Should 'migratory' fish be used to designate potential or candidate hot spots?

   Presently migratory fish are used to designate potential hot spots and non-migratory fish to designate candidate hot spots. At present we treat anadromous fish (e.g., striped bass and salmon) as migratory and de-emphasize their use for designating hot spots. But striped bass spend a lot of time in San Francisco Bay and do show the same chemical contaminants as other species in San Francisco Bay.

Fish behavior is hard to characterize. Species may spend different portions of their life history in different habitats and at different trophic levels. The size of the area over which they forage may vary. Still fish in different areas (especially in southern California) have shown different chemical levels.

So what is a workable definition of migratory vs. a non-migratory fish species? How often does a fish have to leave a waterbody to be considered migratory? For how long? At what life stage? Should we make these distinctions and use them for sampling design and program goals?

4. Is it necessary to have sediment chemistry in addition to tissue bioaccumulation data to designate a human health toxic hot spot? Should this be part of the weight-of-evidence?

5. What tissue chemistry values can be used to interpret bioaccumulation data for hot spot designation? FDA action levels? National Academy of Sciences (1973, guidelines for fish-eating birds and mammals)? SWRCB Maximum Tissue Residue Levels from the Inland Surface Waters and Bays and Estuaries Plans? US EPA 'screening values' from Guidance for Assessing Chemical Contaminant Data for use in Fish Advisories?

BENTHIC COMMUNITY ISSUE PAPER

Characterization of Benthic Community Degradation for San Diego Report (excerpted from the San Diego Report text)

Data Analyses and Interpretation

The identification of benthic degraded and undegraded habitat (as determined by macrobenthic community structure) was conducted using a cumulative, weight-of-evidence approach. Tests were employed without prior knowledge or integration of results from laboratory exposures or chemical analyses. Analyses were performed to identify relationships between community structure within and between each station or site. This included diversity/evenness indices, analyses of habitat and species composition, construction of dissimilarity matrices for pattern testing, assessment of indicator species and development of a benthic index, cluster and ordination (multidimensional scaling) analyses. Initially, a triangular correlation matrix was produced from species density data from each site using the Systat® statistical program. From this matrix several tests for association of variables were performed. The tests employed are common in marine and estuarine benthic community analyses and are well-documented in the literature (Field *et al.*, 1982; Pearson *et al* 1983; Swartz *et al.*, 1985; Gray, 1989; Clark and Ainsworth, 1993). Classification analysis was employed to demonstrate site-related community patterns such as species dominance. Cluster analysis is a multivariate procedure for detecting natural groupings in data, and, for our purposes, data were grouped by average similarities in total composition and species abundance (Krebs, 1989). The average-linkage method calculates similarity between a pair of cluster groups as the average similarity among entities in the two groups. Species information is used to compute similarity index values. Grouped stations were clustered at a conservative distance limit of 50-60% similarity, however, this level is purely arbitrary. Because classification analyses have the tendency to force data into artificially distinct groups, another method (*e.g.*, multi-dimensional scaling) was used to confirm the validity of group clusters and site similarity. Ordination analyses are useful because it enables one to see multidimensional gradients in data rather than just groupings (Smith, personal communication).

Multi-dimensional scaling (MDS) is used extensively in the analyses of benthic communities, particularly in estuarine and marine pollution studies. MDS is a procedure for fitting a set of points in space such that the distance between points correspond to a given set of dissimilarities. This technique is more flexible than principal co-ordinate analyses when handling the

large number of zero counts generally characteristic of species-samples matrices. Nonmetric MDS analyses were performed using Systat®. For a detailed account of MDS statistical procedures, see Clarke and Ainsworth (1993) and Warwick and Clarke (1993). Inferences from the resultant ordination are also presented. It is important to note that, as with cluster analyses, MDS results are not definitive and must be used in conjunction with additional ecological information. MDS results are based on total species number and numbers of individuals. Inferences from the resultant ordination are also presented.

After classification and ordination patterns were determined, the raw data were reevaluated to assess which species may have influenced the observed patterns. Indicator species were then selected on the basis of a literature review (*i.e.*, distribution, life history strategies and habitat preference), by recommendations from other experienced benthic taxonomists, and review of the raw data. Initially, community analyses were conducted as a per "site" comparison. Later, it was decided analyses also be expanded to a per "station" comparison to produce a more definitive data set for the reference pool. The extended analysis of station variability was performed using the benthic index.

Benthic assemblages have many attributes which make them reliable and sensitive indicators of the ecological condition in estuarine environments. The following procedure summarizes the construction and application of the benthic index used to reliably discriminate between degraded and undegraded conditions at sites in the San Diego Bay Region. Although there are problems with trying to simplify complex biological communities, we attempted to develop a quantitative method which creates a partition between degraded and undegraded areas. Polluted sites can not be conclusively identified using results from benthic community analyses alone, but these analyses impartially describe "environmentally stressed" areas. This benthic index is based on species (indicators), and group (general taxa) information. The index also evaluates community parameters such as species richness, abundance and presence of pollution indicators, which identify the extremes of the community characteristics. Sites are ranked according to these extremes and are represented by a single value. In general, decreasing numbers of species, increasing numbers of individuals, and decreasing diversity values are common responses observed near polluted areas. These trends are incorporated into the index. One of the important restrictions with the existing method is it evaluates this limited San Diego Bay benthic data set when dividing groups for categorization. Construction and subsequent validation of this simplified benthic index are loosely based on criteria developed by several agencies, including USEPA-EMAP and SCCWRP. However, the benthic index developed by USEPA-EMAP (Weisberg *et al.*, 1993) included several environmental variables in its construction

(*e.g.* dissolved O_2), while the index for San Diego Bay data used only biological parameters. Briefly, the following major steps are followed in constructing and validating this benthic index:

1. Degraded and undegraded (*i.e.*, reference condition) stations are identified on the basis of measured environmental and biological variables.

2. A list of "candidate" parameters is developed using species abundance data. The list included metrics having ecological relevance (*e.g.*, species diversity indices, etc.) which potentially may be used to discriminate between degraded and reference areas.

3. A value for each candidate parameter (*i.e.*, diversity, abundance, taxonomic composition) is calculated for each station (*e.g.*, total species per station, total individuals per station, total crustaceans species per station, total number of polychaete individuals, total amphipods per station, etc.).

4. Range of values per metric is determined (lowest to highest value).

5. Quartiles from that range are determined.

6. Ranking within quartiles are assigned: upper range quartile=2, lower range quartile=0, middle quartile=1. Apply these calculations on the metrics from step 3.

7. The index is defined by values of 0, 1, or 2. A value of 0 defines the degraded (detectable stress) stations(s), and 2 identifies environmentally undegraded stations(s). Stations with an index value of 1 are considered transitional communities, which are neither degraded nor reference stations. Transitional stations have species or other parameters which indicate both degraded and undegraded habitats. These stations are investigated further to determine the cause of ambiguity of the transitional status.

8. Relative abundance of indicator species (both degraded and undegraded habitat indicators) per station is assessed.

A primary concern regarding the benthic index is how well it fulfills the objective of discriminating among degraded and

undegraded estuarine conditions. This simplified version forms the basis for ongoing iterative procedures involved in construction of an index. This index will include a variety of indicator values (Bascom *et al.*, 1978; Kerans *et al.*, 1994; EcoAnalysis *et al.*, 1995) for future applications of the assessment of benthic community structure. The following sections report results of benthic community analyses based solely on composition and abundance of macrobenthic species from sediment cores throughout San Diego Bay and its vicinity. Environmental parameters (*e.g.*, total organic carbon levels and sediment grain size range) and other factors capable of influencing benthic composition were examined, but not evaluated in conjunction with the data presented here. Those data are examined later in sections which address correlative analyses.

In this study, bioeffects are required to be demonstrated in relation to properly selected reference sites and to occur in association with significant pollutant levels. The following evidence for undegraded (possible reference) and degraded (possible contaminated) sites was based on benthic community "quality" at each site and station. Benthic community structure was evaluated as an indicator of environmentally degraded or undegraded areas and not as a pollution or contamination indicator. Benthic reference sites were determined predominantly by analyses of specific indicator species and groups (*e.g.*, amphipods). These species are generally not found in polluted or disturbed areas.

It is our intention in this section to clearly describe the condition of macrobenthic communities from sampling areas. Definitions of degraded, transitional, and undegraded used in this section are adopted from several papers (Bascom *et al.*, 1978; Pearson and Rosenberg, 1978; Schindler, 1987; Swartz *et al.*, 1985; Underwood and Peterson, 1988). Although the boundaries set in Bascom *et al.* (1978) were based on food supply and not on toxicants, the same general principles apply to this study. In benthic analyses, the term "degraded" does not refer to a community response to significant levels of toxic chemicals. Degraded areas are those which contain significant numbers of opportunistic species, in the absence of non-opportunistic species, and have relatively low species diversity. Correlations are later used to determine if community profiles are influenced by chemistry or by natural environmental disturbances. Sites and stations which are categorized as "undegraded" have high species diversity, high proportional abundance of amphipods and other crustaceans, while noting there are a few exceptions to this rule (*e.g., Grandidierella japonica*, etc.). Undegraded areas generally contain species which are known to be sensitive to pollutants. Transitional sites and stations are those which are not confidently partitioned into the other two categories. These areas may solicit further study. Overall, an integration of data from laboratory exposures, chemical analyses, and benthic

community assessments provide strong complementary evidence of the degree of pollution-induced degradation in aquatic communities. The following data analyses were conducted on a per site basis using sample replicates (n=5) at each sampling location. (Table 6). An analysis also was performed using per station data (n=1) and is presented later in this section. Tests included classification and ordination analyses, diversity measurements, construction of a benthic index, and assessment of indicator species.

Characterization of Benthic Community Degradation for Southern California Coastal Lagoons Project Report (Summarized from internal draft report text)

The methodology described in the previous section (above) which was employed for the San Diego Report for classifying benthic community degradation was refined for use in classifying benthic communities at sites in the Southern California Coastal Lagoons Project. A brief summary of this revised methodology for the Southern California Coastal Lagoons Project is described below.

Benthic Index

The benthic index used in this study is a refined version of the index used in the San Diego BPTCP Report. It combines the use of benthic community data with the presence of positive or negative indicator species to give a measure of the relative degree of degradation of the benthic fauna. It does not require the presence of uncontaminated reference stations, and does not refer to data beyond that collected in this study. Other benthic indices often rely on apriori assumptions, particularly the presence of uncontaminated reference sites, which can lead to false results if the assumptions are not met.

Community Data

Two aspects of the community data were used in the benthic index: the total number of species, and the number of crustacean species. An increase in species richness is one of the most long-standing indicators of healthy environments. While a variety of indices have been developed to quantify species richness in absolute terms, for a study limited in spatial scale, as was this one, total number of species is as valid as any.

Crustaceans are generally more sensitive to environmental contaminants than most other components of the infauna, particularly polychaetes and bivalves. Species and numerically abundant crustacean faunas on the Pacific coast of the U.S. are generally only found in uncontaminated environments, making the number of crustaceans species an important indicator of overall environmental health.

Indicator species

Eleven of the 168 total species were chosen as indicators species. The bioindicators were chosen based on a review of pertinent literature, known habitat preferences and life history, their abundance over all of the stations, and on discussions with experienced ecologists. The 3 negative indicator species are highly opportunistic annelids which thrive in disturbed, polluted, or marginal environments, and are generally not found in mature, undisturbed communities. The 8 positive indicator species consist of 1 polychaete, 2 bivalves, and 5 crustaceans, and are generally not found in polluted habitats.

Calculation of the Benthic Index

Based on the previous work, it was determined that three levels of index classification would give sufficient resolution to detect possible impacted areas, while being robust enough to reduce false positives. Accordingly, for Total Fauna and Number of Crustacean Species, the total range for the 43 stations were determined. After outliers were removed, the ranges of each were divided into thirds. Those with the lower third were ranked as "1", in the middle third as "2", and in the upper third as "3". For example, the range of crustacean species was 0-15. Station 95004 had 6 crustacean species, so was given a crustacean index of "2". The Total Fauna and Crustacean values were calculated for each station. These two numbers represent two-thirds of the Benthic Index for each station.

The Indicator indices were based mostly on presence or absence, with abundance of negative species given additional weight. Stations were given a negative Indicator Index of "1" if they contained at least two of the 3 negative species, and had at least one species in the middle third of the range. Stations were given a Positive Indicator Index of "3" if at least 3 of the 8 positive species were present. Stations not ranked either "1" or "3" were ranked "2". There were no stations with an overlap of the positive and negative indicators indices.

To determine the overall benthic index, the Total Fauna, Crustacean Species, and Indicator Species indices were averaged. This resulted in a range of 1 (most impacted) to 3 (cleanest) with 5 gradations between.

Other Benthic Community Issues

- Benthic community composition/summary parameters at a location can be well characterized with many fewer replicates than it takes to level out a species-area curve. What about use of optimization and power analyses (based on variance components estimated from the available data)? Also, what about utilization of number

of species per grab in order to reduce the number of replicates necessary for statistical tests? Bob Smith comments from SPARC 1995.

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WEIGHT-OF-EVIDENCE ISSUE PAPER

Application of Weight of Evidence Approach for San Diego Bay

One of the primary goals of the BPTCP is to establish state guidelines under which contaminated or toxic stations can be designated "toxic hot spots". These guidelines are currently being developed based on data collected throughout the State. Although final guidelines are contingent upon further data analysis, the "toxic hot spot" definition currently utilized by the BPTCP, requires that one or more of the following criteria must be met:

1. The water or sediment exhibits toxicity associated with toxic pollutants, based on toxicity tests acceptable to the SWRCB or the RWQCB. To determine whether toxicity exists, recurrent measurements (at least two separate sampling dates) should demonstrate an effect.

2. Significant degradation in biological populations and/or benthic communities associated with the presence of elevated levels of toxic pollutants.

3. The site exceeds water or sediment quality objectives for toxic pollutants which are contained in appropriate water quality control plans, or exceeds water quality criteria promulgated by the U.S. Environmental Protection Agency.

4. The tissue toxic pollutant levels of organisms collected from the site exceed levels established by the United States Food and Drug Administration (FDA) for protection of human health, or the National Academy of Sciences (NAS) for the protection of human health or wildlife.

Because tissue residues were not analyzed in San Diego Bay (and most BPTCP data sets), criteria are generally limited to the first three. Satisfying any one of these criteria can designate a site a "toxic hot spot". Satisfying more than one criterion and the severity demonstrated within each criterion determines the weighting for which qualitative rankings can be made. In the San Diego report, stations were not be designated as "toxic hot spots", because this designation is still under evaluation and development by the BPTCP. Instead, stations were be prioritized for further evaluation for hot spot status. This priority was be classified as high, moderate, low, or no action and is to be used by State and Regional Water Board staff to direct further investigations at these stations. Each station receiving a high to low priority ranking meets one or more of the first three criteria established above. Those meeting all three criteria were designated as the highest priority for further action.

San Diego stations were evaluated for repeat toxicity (criterion 1) using the reference envelope method, the most conservative measure developed. Only those stations which demonstrated amphipod survival less than 48% in repeated tests, without confounding ammonia, hydrogen sulfide or grain size effects, were considered to exhibit repeat toxicity hits. Because only one critical value could be determined for any of the dilutions of the pore water bioassays, pore water toxicity results were not evaluated for repeat toxicity when prioritizing stations.

Stations with repeat toxicity and elevated chemistry and/or degraded benthic communities, were assigned moderate or high priority. Stations with repeat toxicity, but lacking elevated chemistry or degraded benthic communities, were assigned low priority (Table 6 - Repeat Toxicity Hits).

Stations with only a single toxicity hit were also considered a moderate or high priority, when associated with elevated chemistry and/or degraded benthic communities. Stations with a single toxicity hit, but lacking elevated chemistry or degraded benthic communities, were assigned a low priority (Table 6 - Single Toxicity Hits).

Twenty-two stations demonstrated repeat or single toxicity hits but were given a "no action" recommendation at this time (Table 6). These stations had measured grain size, hydrogen sulfide or ammonia concentrations which confound interpretation of the bioassay test results. Chemistry levels were low, or not analyzed, and the benthic community was undegraded or transitional, where sampled. These results provided little or no evidence that these stations should be prioritized for hot spot status.

Stations were evaluated for benthic community condition using the benthic index. Stations determined to be degraded, with elevated chemistry and/or toxicity, were assigned a moderate or high priority. Stations determined to be degraded, but which did not demonstrate elevated chemistry or toxicity, were assigned a low priority. Transitional and undegraded stations were not considered a priority unless chemical or toxicity results initially prioritized the stations. (Table 7 - Degraded Benthics)

Stations were evaluated for elevated chemistry (criterion 3) using an ERM quotient >14.6 or a PEL quotient >16.3. It was determined these values are statistically above the 90% confidence interval of summary quotients from all San Diego stations analyzed. These quotients were used to identify stations where multiple pollutants were near or above established ERM and PEL guidelines (Table 7-Chemistry-Summary Quotients). 100% of the stations analyzed for benthics were found to be degraded when chemical analysis demonstrated a summary ERM quotient above 14.6. Although the 21 stations in Table 7

TABLE 6
FUTURE INVESTIGATION PRIORITY LIST FOR SAN DIEGO BAY REGION

Station #	Station	IDORG	Leg	Fines	Ammoni	Rhepox. Survival	>4x ERM or >5.9x PEL	ERMQ	PELQ	Benthics	Comments	PRIORITY
	REPEAT TOXICITY HITS											
90009.0	28 SWARTZ	158	7	64.00	0.002	0.00	Chlordane, DDT	26.77	29.37	not analyzed	ELEVATED CHEM	HIGH
90009.0	28 SWARTZ (7TH ST CHANNEL Q1)	893	23	23.84	0.016	5.00	Chlordane	12.56	15.64	DEGRADED	TRIAD HIT	HIGH
93228.0	SEVENTH ST CHANNEL Q1 (x6)	895	23	60.67	0.010	2.00	Chlordane	40.15	48.55	DEGRADED	TRIAD HIT	HIGH
93179.0	NAVAL SHIPYARDS O3 (x1)	797	19	79.01	0.539	20.00		17.49	23.47	not analyzed	ELEVATED CHEM	HIGH
93179.0	NAVAL SHIPYARDS O3 (x1)-REP 1	1122	27	79.81	0.059	44.00		18.59	23.45	not analyzed	ELEVATED CHEM	HIGH
90043.0	CORONADO WHARF	192	12	36.00	0.684	29.00		2.94	3.72	not analyzed	NH3>.6	NO ACTION
90043.0	CORONADO WHARF-REP 1	1156	28	20.77	0.423	33.00		2.02	2.82	not analyzed		LOW
90043.0	CORONADO WHARF-REP 2	1157	28	77.38	0.224	43.00		11.95	15.56	not analyzed	MODERATE CHEM	LOW
90030.0	BF SCHROEDER SITE F	179	12	94.00	0.066	47.00	PAHs	17.61	26.93	not analyzed	FINES>90%, ELEVATED CHEM	MODERATE
90030.0	BF SCHROEDER SITE F	749	16	92.00	0.204	43.00		not analyzed	not analyzed	not analyzed	FINES >90%	NO ACTION
93122.0	SOUTH SHORE-CORONADO DD3 (x1)	725	16	89.00	0.740	23.00		7.22	9.69	not analyzed	NH3>0.6, MODERATE CHEM	LOW
93122.0	S.S.- CORONADO DD3 (x1) REP 1	1013	24	65.52	0.463	33.00		5.33	7.34	not analyzed		LOW
90036.0	STORM DRAIN- ROHR CHANNEL	185	5	64.00	0.894	27.00		2.99	4.02	not analyzed	NH3>0.6	NO ACTION
90036.0	STORMDRAIN EA (ROHR CH.) REP 3	1024	24	25.65	0.119	1.00		1.74	2.27	not analyzed		LOW
90036.0	STORMDRAIN EA (ROHR CH.) REP 1	1022	24	24.00	0.136	0.00		2.46	2.80	not analyzed		LOW
93125.0	SILVER STRAND FF4 (x4) REP 1	1016	24	22.68	0.514	38.00		2.21	3.05	not analyzed		LOW
93125.0	SILVER STRAND FF4 (x4) REP 2	1017	24	15.44	0.720	22.00		2.00	2.76	not analyzed	NH3>0.6	NO ACTION
93125.0	SILVER STRAND FF4 (x4) REP 3	1018	24	19.05	0.484	22.00		2.25	3.22	not analyzed	H2S HIGH	NO ACTION
93158.0	SOUTH BAY GG1 (x1) REP 1	1035	24	53.67	0.043	33.00		2.98	4.18	not analyzed		LOW
93158.0	SOUTH BAY GG1 (x1) REP 2	1036	24	62.76	0.108	39.00		3.18	4.36	not analyzed		LOW
93158.0	SOUTH BAY GG1 (x1) REP 3	1037	24	51.74	0.072	46.00		2.61	3.66	not analyzed		LOW
90024.0	SDNI-N1	173	7	69.00	0.684	40.00		5.60	7.86	not analyzed	NH3>0.6	NO ACTION
90025.0	SDNI-N5	174	7	73.00	0.925	7.00		5.15	7.60	not analyzed	NH3>0.6	NO ACTION
93188.0	CARRIER BASE V1 (x2)	806	19	40.85	2.593	37.00		3.87	5.42	not analyzed	NH3>0.6	NO ACTION
90025.0	SDNI-N5 (CARRIER BASE V2)	899	23	75.96	0.643	37.00		5.23	7.20	UNDEGRADED	NH3>0.6	NO ACTION
93232.0	CARRIER BASE V2 (x7)	1001	23	63.79	0.773	35.00		5.22	7.46	UNDEGRADED	NH3>0.6	NO ACTION
90057.0	5 SDG&E	206	12	98.00	0.011	25.00		2.72	3.98	not analyzed	FINES>90%	NO ACTION
90057.0	5 SDG&E REP 1	1019	24	98.45	0.046	41.00		3.71	5.18	not analyzed	FINES>90%	NO ACTION
90057.0	5 SDG&E REP 2	1020	24	97.80	0.011	39.00		3.37	4.74	not analyzed	FINES>90%	NO ACTION
90057.0	5 SDG&E REP 3	1021	24	97.22	0.032	31.00		3.31	4.68	not analyzed	FINES>90%	NO ACTION
	SINGLE TOXICITY HITS											
90002.0	12 SWARTZ(DOWNTOWN ANCH)-REP 1	878	22	48.25	1.836	15.00	Chlordane	30.74	38.46	DEGRADED	TRIAD HIT	HIGH
90007.0	25 SWARTZ	156	7	67.00	0.004	37.00	Mercury	13.57	16.62	not analyzed	ELEVATED CHEM, SITE DEGRADED IN LEG 23	MODERATE
90008.0	27 SWARTZ	157	7	66.00	0.010	29.00		5.73	8.55	not analyzed	SITE DEGRADED IN LEG 23	MODERATE
90022.0	P SWARTZ	171	7	87.00	0.008	38.00		12.88	18.52	not analyzed	ELEVATED CHEM, SITE DEGRADED IN LEG 22	MODERATE
93181.0	NAVAL SHIPYARDS O6 (x1)	799	19	89.12	0.042	45.00		15.51	21.44	not analyzed	ELEVATED CHEM	MODERATE
93210.0	NAVAL BASE/SHIPYARDS O4 (x1)	863	22	48.75	0.775	37.00		16.15	17.76	DEGRADED	NH3>0.6, ELEVATED CHEM	MODERATE
90010.0	31 SWARTZ	159	6	85.00	1.291	39.00		not analyzed	not analyzed	not analyzed	NH3>0.6, SITE DEGRADED IN LEG 23	LOW
90039.0	CL	188	12	24.00	0.090	38.00	Chlordane, DDT	13.86	17.71	not analyzed	ELEVATED CHEM	MODERATE
93178.0	NAVAL SHIPYARDS O2 (x1)	796	19	55.32	0.350	20.00		10.85	14.40	not analyzed		LOW
93166.0	NAVY ESTUARY G2 (x1)	779	18	23.62	1.129	20.00		5.81	7.79	not analyzed	NH3>0.6	NO ACTION
93118.0	TIJUANA R. ESTUARY HH1 (x2)	713	15	60.00	0.187	30.00	DDE	5.80	6.66	not analyzed	ELEVATED CHEM	MODERATE
90018.0	D DE LAPPE	748	16	42.00	0.039	19.00		not analyzed	not analyzed	not analyzed		LOW
90023.0	NM SANDBAG	172	7	27.00	0.378	32.00		3.12	4.55	not analyzed		LOW
90050.0	10 SWARTZ	199	7	81.00	0.004	47.00		4.19	6.41	not analyzed		LOW
90051.0	16 SWARTZ (INTERCONT. MARINA)	818	20	41.33	3.340	1.00		3.49	4.80	TRANSITIONAL	NH3>0.6, SITE TRANSITIONAL IN LEG 20	LOW
90055.0	43 SWARTZ	204	7	64.00	0.075	37.00		4.12	5.71	not analyzed		LOW
90102.0	HARBOR BRIDGE 71A	256	7	75.00	0.113	14.00		2.69	3.77	not analyzed		LOW
90104.0	WEST BASIN ENTRANCE (71C) REF	275	12	74.00	1.046	13.00		3.43	4.88	not analyzed	NH3>0.6	NO ACTION
93106.0	MISSION BAY A2 (x1)-REP 2	1102	27	94.52	0.106	25.00		3.49	4.43	not analyzed	FINES >90%	NO ACTION
93117.0	SAN DIEGO RIVER B2 (x2)	1029	24	92.05	0.110	0.00		not analyzed	not analyzed	not analyzed	FINES >90%	NO ACTION
93119.0	TIJUANA R. ESTUARY HH1 (x1)	714	15	84.00	0.224	22.00	DDE, DDT	not analyzed	not analyzed	not analyzed	ELEVATED CHEM	MODERATE
93127.0	SOUTH BAY GG2 (x1)	1028	24	43.93	0.096	47.00		not analyzed	not analyzed	not analyzed		LOW
93128.0	SOUTH BAY GG5 (x1)	1033	24	96.80	0.031	27.00		not analyzed	not analyzed	not analyzed	FINES >90%	NO ACTION
93132.0	CORONADO CAYS T3 (x1)	1025	24	90.97	0.004	47.00		not analyzed	not analyzed	not analyzed	FINES >90%	NO ACTION
93138.0	SHELTER ISLAND E3 (x2)	741	16	60.00	0.020	29.00		3.29	4.38	not analyzed		LOW
93148.0	CHANNEL-CORONADO Y1 (x2)	751	16	23.00	0.525	47.00		2.71	3.47	not analyzed		LOW
93154.0	NORTH SHORE-MOUTH CC4 (x1)	763	17	32.94	0.836	31.00		not analyzed	not analyzed	not analyzed	NH3>0.6	NO ACTION
93159.0	SOUTH BAY GG3 (x1)	768	17	58.87	0.675	21.00		not analyzed	not analyzed	not analyzed	NH3>0.6	NO ACTION
93174.0	TIJUANA R. ESTUARY HH3 (x2)	787	18	70.63	0.282	6.00		4.60	5.58	not analyzed		LOW
93175.0	TIJUANA R. ESTUARY HH3 (x3)	788	18	92.67	0.141	10.00	DDE, DDT	not analyzed	not analyzed	not analyzed	FINES >90%, ELEVATED CHEM	MODERATE
93219.0	SWEETWATER CH. JJ1 (x1)-REP 2	876	22	60.74	0.319	31.00		2.25	3.06	TRANSITIONAL		LOW

TABLE 7
FUTURE INVESTIGATION PRIORITY LIST FOR SAN DIEGO BAY REGION

Station #	Station	IDORG	Leg	Fines	Ammoni	Rhepox. Survival	>4x ERM or >5.9x PEL	ERMQ	PELQ	Benthics	Comments	PRIORITY
	DEGRADED BENTHICS											
90007.0	25 SWARTZ (NAVAL BASE/SY O10)	887	23	81.62	0.014	86.00		11.74	15.74	DEGRADED		LOW
93223.0	NAVAL BASE/SHIPYARD O10 (x2)	888	23	85.99	0.016	79.00		14.27	20.25	DEGRADED	ELEVATED CHEM	MODERATE
93224.0	NAVAL BASE/SHIPYARD O10(x6)	889	23	48.07	0.010	90.00	Zinc	10.56	15.36	DEGRADED	ELEVATED CHEM	MODERATE
93211.0	NAVAL BASE/SHIPYARDS O4 (x2)	864	22	70.59	0.158	86.00	ntimony, Copper, PC	24.89	29.83	DEGRADED	ELEVATED CHEM	MODERATE
90021.0	K SWARTZ (NAVAL BASE O4)	862	22	69.03	0.060	93.00		10.55	14.81	DEGRADED		LOW
90006.0	23 SWARTZ (NAVAL BASE O7)	865	22	63.34	0.054	92.00	Chlordane	18.15	23.62	DEGRADED	ELEVATED CHEM	MODERATE
93212.0	NAVAL BASE/SHIPYARDS O7 (x1)	866	22	32.88	0.026	91.00	Chlordane	10.29	13.52	DEGRADED	ELEVATED CHEM	MODERATE
93213.0	NAVAL BASE/SHIPYARDS O7 (x4)	867	22	69.06	0.010	94.00	Chlordane	21.00	27.21	DEGRADED	ELEVATED CHEM	MODERATE
93227.0	SEVENTH ST CHANNEL O1 (x5)	894	23	53.40	0.076	79.00	Chlordane	14.49	18.73	DEGRADED	ELEVATED CHEM	MODERATE
93206.0	DOWNTOWN PIERS K1 (x11)	848	21	56.03	0.048	95.00	PAHs	17.08	29.59	DEGRADED	ELEVATED CHEM	MODERATE
90004.0	15 SWARTZ (G ST. PIER MARINA)	849	21	67.23	0.220	77.00		8.37	11.32	DEGRADED		LOW
93207.0	G ST. PIER MARINA L1 (x4)	850	21	79.29	0.173	89.00		7.91	10.65	DEGRADED		LOW
90022.0	P SWARTZ (NAVAL BASE O12)	868	22	88.09	0.061	91.00	PAHs	16.64	23.33	DEGRADED	ELEVATED CHEM	MODERATE
93214.0	NAVAL BASE/SHIPYARDS O12 (x3)	869	22	56.64	0.031	93.00		7.88	10.92	DEGRADED		LOW
93215.0	NAVAL BASE/SHIPYARDS O12 (x4)	870	22	64.17	0.017	88.00		6.20	8.92	DEGRADED		LOW
90008.0	27 SWARTZ (NAVAL BASE/SH O13)	890	23	59.15	0.008	92.00		7.23	10.36	DEGRADED		LOW
93225.0	NAVAL BASE/SHIPYARD O13 (x1)	891	23	74.94	0.013	81.00		12.03	17.33	DEGRADED	ELEVATED CHEM	MODERATE
93226.0	NAVAL BASE/SHIPYARD O13 (x3)	892	23	79.38	0.019	91.00		10.82	15.91	DEGRADED		LOW
90010.0	31 SWARTZ (MARINE TERMINAL R3)	896	23	38.75	0.077	86.00		2.78	4.11	DEGRADED		LOW
93229.0	MARINE TERMINAL R3 (x1)	897	23	69.13	0.109	70.00	PAHs	14.55	22.94	DEGRADED	ELEVATED CHEM	MODERATE
93230.0	MARINE TERMINAL R3 (x3)	898	23	76.64	0.056	63.00		7.77	11.51	DEGRADED		LOW
93116.0	SAN DIEGO RIVER B1 (x4)-REP 1	881	22	44.01	0.216	92.00		4.87	5.90	DEGRADED		LOW
93116.0	SAN DIEGO RIVER B1 (x4)-REP 2	882	22	92.30	0.098	92.00	Chlordane	9.12	11.87	DEGRADED	ELEVATED CHEM	MODERATE
93116.0	SAN DIEGO RIVER B1 (x4)-REP 3	883	22	92.25	0.162	78.00	Chlordane	12.29	15.92	DEGRADED	ELEVATED CHEM	MODERATE
90028.0	NSB-M1 (SUB BASE C2)	871	22	79.41	0.078	84.00	PAHs	9.71	15.88	DEGRADED	ELEVATED CHEM	MODERATE
93216.0	SUB BASE C2 (x1)	872	22	36.48	0.079	93.00		3.53	5.39	DEGRADED		LOW
93217.0	SUB BASE C2 (x3)	873	22	72.12	0.074	81.00		8.03	12.59	DEGRADED		LOW
90012.0	34 SWARTZ (C.V. YACHT BASIN)	824	20	80.17	0.334	57.00		2.61	3.94	DEGRADED		LOW
93196.0	CHULA V. YACHT BASIN S1 (x1)	825	20	96.81	0.260	76.00		4.36	6.84	DEGRADED		LOW
93197.0	CHULA V. YACHT BASIN S1 (x3)	826	20	94.23	0.165	79.00		3.37	5.00	DEGRADED		LOW
90003.0	14 SWARTZ (DOWNTOWN PIERS)	846	21	59.57	0.084	70.00		5.46	7.51	DEGRADED		LOW
93205.0	DOWNTOWN PIERS K1 (x9)	847	21	48.18	0.167	84.00	PAH	5.64	8.49	DEGRADED	ELEVATED CHEM	MODERATE
93107.0	MISSION BAY A3 (x1)-REP 1	853	21	93.03	0.075	57.00		5.51	6.83	DEGRADED		LOW
93107.0	MISSION BAY A3 (x1)-REP 2	854	21	92.25	0.046	77.00		6.42	7.73	DEGRADED		LOW
93204.0	CORONADO CAYS T2 (x2)	845	21	59.85	0.062	82.00		2.63	3.73	DEGRADED		LOW
93220.0	SWEETWATER CH. JJ1 (x8)-REP 3	877	22	36.99	0.129	81.00		1.78	2.45	DEGRADED		LOW
93208.0	G ST. PIER MARINA L1 (x5)	851	21	85.24	0.064	83.00		12.18	16.11	DEGRADED		LOW
	CHEMISTRY- Summary Quotients											
90020.0	G DE LAPPE	169	12	82.00	0.020	49.00		16.13	19.41	not analyzed	ELEVATED CHEM	MODERATE
90020.0	G DE LAPPE-REP 1	1104	27	82.53	0.086	65.00		17.45	21.68	not analyzed	ELEVATED CHEM	MODERATE
90020.0	G DE LAPPE-REP 2	1105	27	84.43	0.087	59.00		17.33	21.53	not analyzed	ELEVATED CHEM	MODERATE
90020.0	G DE LAPPE-REP 3	1106	27	82.37	0.049	57.00		15.72	19.84	not analyzed	ELEVATED CHEM	MODERATE
90030.0	BF SCHROEDER SITE F-REP 1	1144	28	93.76	0.192	70.00		15.76	21.77	not analyzed	ELEVATED CHEM	MODERATE
90030.0	BF SCHROEDER SITE F-REP 2	1145	28	96.04	0.616	76.00	PAHs	16.58	23.52	not analyzed	ELEVATED CHEM	MODERATE
90030.0	BF SCHROEDER SITE F-REP 3	1146	28	91.74	0.017	68.00		17.00	22.41	not analyzed	ELEVATED CHEM	MODERATE
93178.0	NAVAL SHIPYARDS O2 (x1)-REP 1	1119	27	51.95	0.185	61.00		15.47	19.80	not analyzed	ELEVATED CHEM	MODERATE
93178.0	NAVAL SHIPYARDS O2 (x1)-REP 2	1120	27	61.76	0.145	66.00	PCBs	19.38	24.82	not analyzed	ELEVATED CHEM	MODERATE
93178.0	NAVAL SHIPYARDS O2 (x1)-REP 3	1121	27	46.68	0.168	67.00	PCBs	20.77	25.07	not analyzed	ELEVATED CHEM	MODERATE
93181.0	NAVAL SHIPYARDS O6 (x1)-REP 1	1110	27	93.71	0.071	53.00		11.98	16.72	not analyzed	ELEVATED CHEM	MODERATE
93181.0	NAVAL SHIPYARDS O6 (x1)-REP 2	1111	27	92.52	0.021	48.00		13.73	18.61	not analyzed	ELEVATED CHEM	MODERATE
93181.0	NAVAL SHIPYARDS O6 (x1)-REP 3	1112	27	94.34	0.037	65.00		15.14	21.01	not analyzed	ELEVATED CHEM	MODERATE
90022.0	P SWARTZ-REP 1	1107	27	84.62	0.061	58.00	PAHs	17.30	23.75	not analyzed	ELEVATED CHEM	MODERATE
90022.0	P SWARTZ-REP 2	1108	27	80.73	0.073	61.00	PAHs	18.35	27.02	not analyzed	ELEVATED CHEM	MODERATE
90022.0	P SWARTZ-REP 3	1109	27	87.48	0.038	54.00	PAHs	18.40	26.44	not analyzed	ELEVATED CHEM	MODERATE
93179.0	NAVAL SHIPYARDS O3 (x1)-REP 2	1123	27	88.89	0.049	51.00		17.82	22.50	not analyzed	ELEVATED CHEM	MODERATE
93179.0	NAVAL SHIPYARDS O3 (x1)-REP 3	1124	27	88.24	0.115	78.00	Antimony	22.02	25.51	not analyzed	ELEVATED CHEM	MODERATE
93184.0	NAVAL SHIPYARDS O11 (x1)	802	19	81.41	0.070	53.00	DDT	20.34	27.23	not analyzed	ELEVATED CHEM	MODERATE
93177.0	NAVAL SHIPYARDS O1 (x1)	795	19	28.88	0.023	50.00	PAHs	11.44	18.21	not analyzed	ELEVATED CHEM	MODERATE
90017.0	C DELAPPE	166	6	71.00	0.840	64.00	PAHs	19.60	29.72	not analyzed	ELEVATED CHEM	MODERATE
	CHEMISTRY- Individual Quotients											
93162.0	SUB BASE C3 (x1)	775	18	83.09	0.585	53.00	PAHs	6.10	9.35	not analyzed	ELEVATED CHEM	LOW
93107.0	MISSION BAY A3 (x1)-REP 3	855	21	94.34	0.145	73.00	Chlordane	9.25	11.46	TRANSITIONAL	ELEVATED CHEM, SITE TRANSITIONAL IN LEG 21	MODERATE
93221.0	DOWNTOWN ANCH. J1 (x1)-REP 2	879	22	83.50	0.143	83.00	Chlordane	10.03	13.04	UNDEGRADED	ELEVATED CHEM	LOW
90037.0	STORMDRAIN E(GRAPE ST.)-REP 3	1161	29	64.02	0.290	85.00	Chlordane	11.46	14.94	not analyzed	ELEVATED CHEM	LOW
93141.0	COMMERCIAL BASIN F3 (x1)-REP 3	1170	29	70.09	0.057	70.00	Mercury	10.77	13.79	not analyzed	ELEVATED CHEM	LOW
93116.0	SAN DIEGO RIVER B1 (x4)	711	15	77.00	0.137	88.00	Chlordane	not analyzed	not analyzed	not analyzed	ELEVATED CHEM, SITE DEGRADED IN LEG 22	MODERATE
93120.0	TIJUANA R. ESTUARY HH2 (x1)	715	15	55.00	0.087	85.00	DDE	not analyzed	not analyzed	not analyzed	ELEVATED CHEM	LOW
93121.0	TIJUANA R. ESTUARY HH2 (x5)	716	15	59.00	0.010	85.00	DDE	not analyzed	not analyzed	not analyzed	ELEVATED CHEM	LOW
93174.0	TIJUANA R. EST. HH3 (x2)-REP 3	1152	28	91.38	0.084	80.00	DDE	5.75	6.34	not analyzed	ELEVATED CHEM	LOW

(CHEMISTRY-Summary Quotients) did not have benthic community analysis performed, it is likely that these stations will demonstrate degraded benthic communities, when analyzed. In consideration of this concern, all stations with elevated chemistry, based on summary quotients, were assigned a moderate priority ranking.

In situations where high summary quotient values were not found, but where any single chemical concentration exceeded four times (4x) its associated ERM or 5.9 times (5.9x) its associated PEL, the station was also considered to exhibit elevated chemistry. The 4x and 5.9x cutoffs were not statistically determined using the 90% confidence interval as they were with the summary quotients. Values for individual chemical quotients were not normally distributed and transformations did not improve distributions, so statistical determination of confidence limits was not appropriate. Instead, a qualitative examination of the data set indicated that only in the top 10th percentile of chemical measurements do values exceed four times their respective ERM or 5.9 times their respective PEL (Table 7 - Chemistry-Individual Chemical Quotients). These cutoffs were used to help identify stations where any single chemical was extremely elevated. Stations with elevated individual chemical quotients and evidence of benthic community degradation were assigned a moderate ranking. Stations which exhibited elevated chemistry, but showed no biological effects, were assigned a low priority.

Stations which satisfied all three of the criteria were considered a triad hit and are given the highest priority ranking. These stations demonstrated toxicity in the bioassay tests, benthic community degradation and elevated chemistry. Three stations (representing two sites) fell in this category. Three stations were given a high priority ranking although not all conditions of the triad were met. These stations demonstrated repeated toxicity and elevated chemistry but no benthic analyses were performed. However, benthic data for stations analyzed in the same proximity, or later sampling of the station, led to the concern that these sites would have been found degraded, if analyzed. In addition, chemical summary quotients at these three stations were at levels which suggest probable benthic community degradation, as discussed earlier. These concerns warranted upgrading these three stations from a moderate priority to a high priority. Forty-eight stations were given moderate priorities and fifty-two were given low priorities, based on the methods of prioritization previously discussed.

Stations were prioritized to assist SWRCB and RWQCB staff in meeting sediment quality management objectives for San Diego Bay. These recommendations were based on scientific evaluation of data collected between 1992 and 1994. They are intended to focus future efforts toward scientifically and economically responsible

characterization of locations which have a high probability of causing adverse effects to aquatic life. This report should be evaluated in conjunction with all available information and additional research when management and policy decisions are made by SWRCB and RWQCB staff.

CONTRIBUTORS TO THE BRIEFING DOCUMENT

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SPARC Recommendations	John Hunt[3], Fred LaCaro[1]
Revised Monitoring Approach	Fred LaCaro, Craig J. Wilson, Max Puckett, Rusty Fairey[4], John Hunt, Brian Anderson[3]
Monitoring Activities	Karen Taberski[5], Bill Croyle[6], Craig J. Wilson

Issue Papers

Toxicity	John Hunt, Brian Anderson
Chemical Association	Rusty Fairey
Bioaccumulation	Robert Brodberg[7], Bruce Gwynne[8]
Freshwater Studies	Val Connor[6], Chris Foe[6], Bill Croyle
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